GROWTH AND YIELD OF AMAN RICE VARIETIES AS AFFECTED BY DIFFERENT METHODS OF UREA APPLICATION

BY

MD. BASHIRUL ISLAM
Reg. No.: 05-1626

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE
IN
AGRONOMY

SEMESTER: JANUARY - JUNE, 2011

Approved by:

.....
(Prof. Dr. Md. Hazrat Ali)
Supervisor

.....
(Prof. Dr. Md. Shahidul Islam)
Co-supervisor

.....
(Prof. Dr. A. K. M. Ruhul Amin)
Chairman
Examination Committe

DEPARTMENT OF AGRONOMY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
PABX: 9110351 & 9144270-79

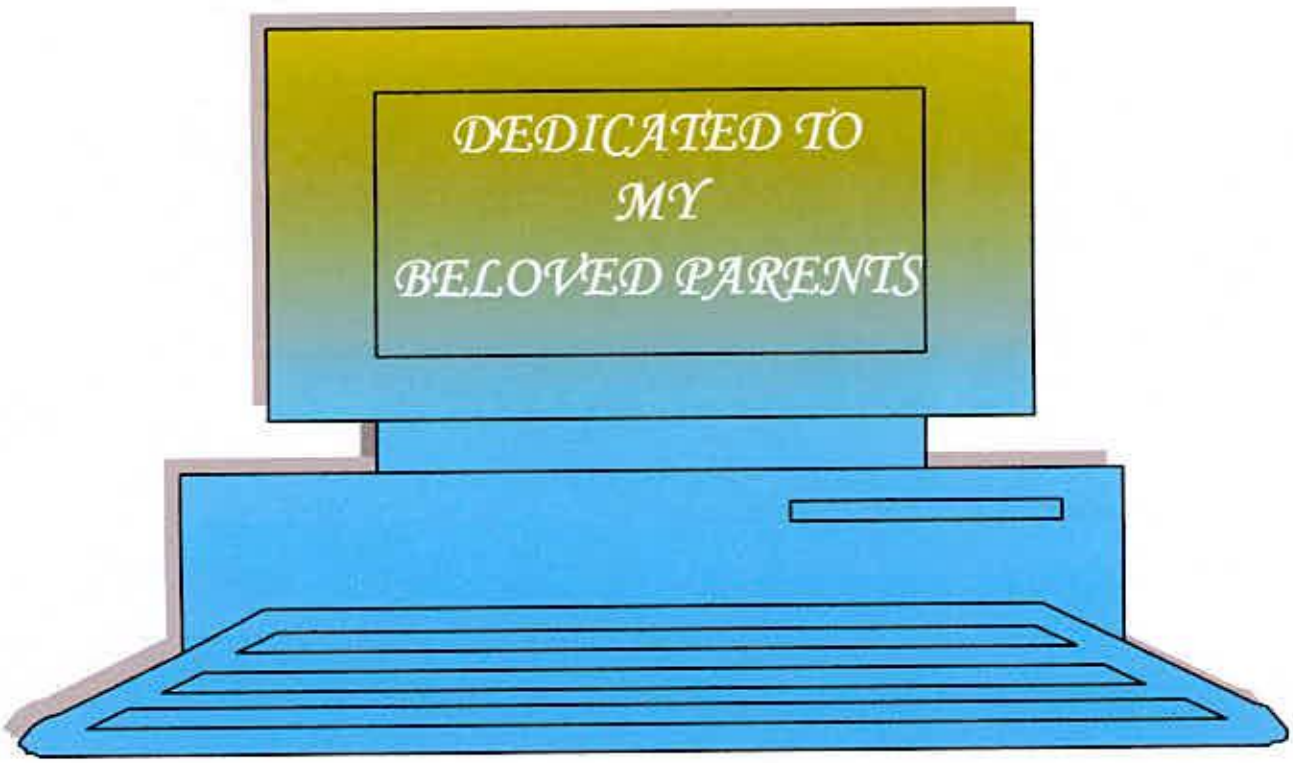
CERTIFICATE

This is to certify that the thesis entitled, **"GROWTH AND YIELD OF AMAN RICE VARIETIES AS AFFECTED BY DIFFERENT METHODS OF UREA APPLICATION"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of ***MASTER OF SCIENCE (M.S.) IN AGRONOMY,*** embodies the result of a piece of bonafide research work carried out by ***MD. BASHIRUL ISLAM,*** **Registration No. 05-01626** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: June, 2011
Dhaka, Bangladesh

(Prof. Dr. Md. Hazrat Ali)
Supervisor


DEDICATED TO
MY
BELOVED PARENTS

ACKNOWLEDGEMENT

Alhamdulillah, all praises are due to the almighty Allah Rabbul Al-Amin for his gracious kindness and infinite mercy in all the endeavors the author to let him successfully complete the research work and the thesis leading to Master of Science.

The author would like to express his heartfelt gratitude and most sincere appreciations to his Supervisor Dr. Md. Hazrat Ali, Professor, Department of Agronomy and former Dean, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, for his valuable guidance, advice, immense help, encouragement and support throughout the study. Likewise, grateful appreciation is conveyed to Co-supervisor Dr. Md. Shahidul Islam, Professor , Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for constant encouragement, cordial suggestions, constructive criticisms and valuable advice to complete the thesis.

The author would like to express his deepest respect and boundless gratitude to all the respected teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic co-operation, and inspirations throughout the course of this study and research work.

The author wishes to extend his special thanks to Dr. Mirza Hasanuzzaman, Sheikh Muhammad Masum, Anisur Rahman, Badiul, Shakila, Nabil, Rohi for their help during experimentation. Special thanks to all other friends for their support and encouragement during this study.

The author is deeply indebted to his father and grateful to his respectful mother, sisters and other relatives for their moral support, encouragement and love with cordial understanding.

Finally, the author would like to appreciate the assistance rendered by the staff of the Department of Agronomy and Agronomy Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka, who have helped him during the period of study.

The author

ABSTRACT

A field experiment was conducted at Agronomy field laboratery, Sher-e-Bangla Agricultural University (SAU), during July- December, 2010 with a view to find out the varietal performance of *aman* rice as affected by different methods of urea application. The experimental treatments included four varieties i.e. BR11, BRRI dhan33, BRRI dhan39, BRRI dhan46 and four urea application methods viz. 15 kg N ha^{-1} as prilled urea at final land preparation + 15 kg N ha^{-1} as prilled urea at 30 DAT+ 15 kgN ha^{-1} as prilled urea 50 DAT; 15 kgN ha^{-1} as prilled urea at 7 DAT + 15 kg N ha^{-1} as prilled urea at 30 DAT + 15 kgN ha^{-1} as prilled urea at 50 DAT; 60 kg N ha^{-1} USG (1.8 g) at 7 DAT; 15 kg N ha^{-1} as prilled urea at 15 DAT+ 15 kg N ha^{-1} as prilled urea 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT. The experiment was laid out in a split- plot design with three replications having urea application in the main plots and variety in the sub-plots. The results showed that urea fertilizer application method significantly influenced plant height, tillering production, leaf area index, effective tillers $hill^{-1}$, filled grains $panicle^{-1}$, unfilled grains $panicle^{-1}$, total grains $panicle^{-1}$, 1000-grain weight, grain yield, straw yield, biological yield and harvest index. Application of USG N as at 7 DAT gave highest yield (7.82 t ha^{-1}) while application of 15 kg N ha^{-1} as prilled urea 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT gave lowest yield (4.88 t ha^{-1}). Varitetal influence were significant on tillering pattern, leaf area index, effective tillers $hill^{-1}$, filled grains $panicle^{-1}$,1000- grain weight, grain yield, straw yield and biological yield. BR11 gave the highest yield (8.17 t ha^{-1}) which was statistically similar with BRRI dhan46 (7.3 t ha^{-1}) while the lowest yield obtained from BRRI dhan33 (2.87 t ha^{-1}). Interaction effect of 1.8 g USG along with BR11 showed the highest effective tillers $hill^{-1}$ (14.00), 1000-grain weight (30.32 g), grain yield (10.67 t ha^{-1}), straw yield (12.00 t ha^{-1}) and biological yield (22.67 t ha^{-1}).

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

AEZ	=	Agro- Ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centi-meter
cv.	=	Cultivar
DAT	=	Days after transplanting
^{0}C	=	Degree Centigrade
DF	=	Degree of freedom
EC	=	Emulsifiable Concentrate
et al.	=	and others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram
HI	=	Harvest Index
HYV	=	High yielding variety
hr	=	hour
IRRI	=	International Rice Research Institute
Kg	=	kilogram
LV	=	Local variety
LYV	=	Low yielding varieties
LSD	=	Least significant difference
m	=	Meter
m^2	=	meter squares
MPCU	=	Mussorie phos-coated urea
MV	=	Modern variety
mm	=	Millimeter
viz.	=	namely
N	=	Nitrogen
ns	=	Non significant
%	=	Percent
CV %	=	Percentage of Coefficient of Variance
P	=	Phosphorus
K	=	Potassium
ppm	=	Parts per million
PU	=	Prilled urea
SAU	=	Sher-e- Bangla Agricultural University
S	=	Sulphur
SCU	=	Sulphur coated urea
t ha^{-1}	=	Tons per hectare
UNDP	=	United Nations Development Program
USG	=	Urea super granules
Zn	=	Zinc

Chapter 1

Introduction

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of about 161.1 million people of Bangladesh (BBS, 2011) and contributes 14.6% to the national GDP (BBS, 2009) and supplies 71% of the total calories and 51% of the protein in a typical Bangladeshi diet (BBS, 1998). Bangladesh with its flat topography, abundant water and humid tropical climate constitutes an excellent habitat for the rice plant (BRRI, 1997a). In Bangladesh, 8.65 million hectare of arable land of which 75% is devoted to rice cultivation (BBS, 2004). Rice is grown in the country under diverse ecosystem like irrigated, rainfed and deep water conditions in three distinct overlapping seasons namely *aus*, *aman* and *boro*. Among these three seasons, the monsoon rice, transplanted *aman* covers the largest area (50.58% of total rice area) and average yield of *aman* rice is 3.33 t ha^{-1} (BBS, 2005). The population of Bangladesh is still growing by two million every year and may increase by another 30 millions over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. During this time total rice area will also shrink to 10.28 million hectares. Rice (clean) yield therefore, needs to be increased from the present 2.44 to 3.74 t ha^{-1} (BRRI, 2006).

Horizontal expansion of rice area is not possible in Bangladesh due to limited land resources and high population density. So, the only avenue left is to increase production of rice by vertical means i.e. management practices. The potential for increased rice production strongly depends on the ability to integrate a better crop management for the different varieties into the existing cultivation systems (Mikkelsen *et al.*, 1995). Variety itself is a genetic factor which contributes a lot in producing yield and yield components of a particular crop. Yield components are directly related to the variety and neighboring environments in which it grows. Earlier literatures indicated that there were marked differences in yield and ancillary characteristics among rice varieties (Chodury and Bhuiyan, 1991). In the year 2005 among the *aman* rice varieties modern varieties covered 67.99% and yield was 2.3 t ha^{-1} on the other hand

local varieties covered 31.91% and yield was 1.37 t ha^{-1} (BBS, 2005). It was the farmers who have gradually replaced the local indigenous low yielding rice varieties by HYV and MV of rice developed by BRRI only because of getting 20% to 30 % more yield $unit^{-1}$ land area (Shahjahan, 2007).

Urea is the principal source of nitrogen, which is the essential element in determining the yield potential of rice (Mae, 1997). Generally urea is broadcast in three equal splits- one as basal dose at the time of final land preparation, one at maximum tillering stage and the remaining one at prior to panicle initiation stage. But under this practices high floodwater, pH, high ammonium N concentration in floodwater, high temperature and high wind speed are the factors, which have been identified to enhance ammonium-N loss. Numerous experiments have shown that the efficiency at which N is utilized by wetland rice is only about 30% of the applied fertilizer N and in many cases even less (Prasad and De Datta, 1979). So, any method of fertilizer N application that reduce the concentration of floodwater N (urea + NH_4) in the rice field will be subjected to less loss of N through NH_3 volatization, algal assimilation, denitrification and surface runoff. Modifying urea materials is an important aspect of N management in rice from the view points of its efficient utilization. These losses of N may be reduced by the deep placement of urea supergranules (USG) instead of broadcasting prilled urea (PU). Point placement of USG can increase the efficiency of N utilization by rice in wet season (Roy, 1985). According to Crasswell and De datta (1980) broadcast application of urea on the surface soil causes losses upto 50% but point placement of USG in 10 cm depth results negligible loss. They also stated that USG placement provides a bonus of nitrogen to the soil. This technology improves N-use efficiency by keeping most of the urea N in the soil close to plant roots and out of the floodwater, where it is more susceptible to loss as gaseous compounds or runoff (Mohanty *et al.*, 1999). Moreover, in conventional urea fertilization, it is often difficult to determine when to apply the fertilizer to achieve optimal results.

Keeping all the points in mind mentioned above, the present piece of research work was under taken with the following objectives.

1. To identify the suitable application methods of nitrogenous fertilizer
2. To compare the performance of HYV varieties of T. *aman* rice
3. To study the effect of point placement of urea supergranules on T. *aman* rice
4. To find out the interaction effect of nitrogenous fertilize application methods and varieties on the growth, yield and yield contributing characters of T. *aman* rice

Chapter 2
Review of literature

REVIEW OF LITERATURE

Variety is an important factor as it influences the plant population unit area^{-1}, availability of sunlight, nutrient competition, photosynthesis, respiration etc. which ultimately influence the growth and development of the crops. In agronomic point of view N management for modern rice cultivation has become an important issue. To minimize the N losses from soil-plant water system and to increase the N use efficiency, suitable techniques are essential for N application in soil. Since 1975 deep placement of urea supergranules (USG) has been practiced pertaining to improve N efficiency. Considering the above points, available literatures were reviewed under variety and application of USG for rice varieties.

2.1 Effect of variety

Variety itself is the genetical factor which contributes a lot for producing yield and yield components. Different researcher reported the effect of rice varieties on yield contributing component and grain yield. Some available information and literature related to the effect of variety on the yield of rice are discussed below.

2.1.1 Effect on growth characters

2.1.1.1 Plant height

Bisne *et al.* (2006) conducted an experiment with eight promising varieties using four CMS lines and showed that plant height differed significantly among the varieties and Pusa Basmati gave the highest plant height, in each line.

Om *et al.* (1998) in an experiment with hybrid rice cultivars ORI 161 and PMS 2A x IR 31802 found taller plants, more productive tillers, in ORI 161 than in PMS 2A x IR 31802.

BINA (1993) evaluated the performance of four rice varieties- IRATOM 24, BR14, BINA 13 and BINA 19. It was found that varieties differed significantly in respect of plant height.

BRRI (1991) reported that plant height differed significantly among BR3, BR11, BR14, Pajam and Zagali varieties in *boro* season.

Hossain and Alam (1991) found that the plant height in modern rice varieties in *boro* season BR3, BR11, BR14 and pajam were 90.4, 94.5, 81.3 and 100.7 cm respectively.

Miah *et al.* (1990) conducted an experiment where rice cv. Nizersail and mutant lines Mut. NSI and Mut. NSS were planted and found that plant height were greater in Mut. NSI than Nizersail.

Shamsuddin *et al.* (1988) conducted a field trial with nine different rice varieties and observed that plant height differed significantly among varieties.

Sawant *et al.* (1986) conducted an experiment with the new rice lines R-73-1-1, R-711 and the traditional cv. Ratna and reported that the traditional cv. Ratna was the shortest.

2.1.1.2 Tillering pattern

Bisne *et al.* (2006) conducted an experiment with eight promising varieties using four CMS lines and showed that tiller number hill^{-1} differed significantly among the varieties and Pusa Basmati gave the highest tiller number hill^{-1} in each line.

Devaraju *et al.* (1998) in a study with two rice hybrids such as Karnataka Rice Hybrid 1 (KRH1) and Karnataka Rice Hybrid-2 (KRI42) using HYV IR20 as the check variety and found that KRH2 out yielded than IR20. In IR20, the tiller number was higher than that of KRH2.

Islam (1995) in an experiment with four rice cultivars *viz.* BR10, BR11, BR22 and BR23 found that the highest number of non bearing tillers hill^{-1} was produced by cultivar BR11 and the lowest number was produced by the cultivar BR10.

Hossain and Alam (1991) also found that the growth characters like total tillers hill^{-1} differed significantly among BR3, BR11, Pajam and Jaguli varieties in *boro* season.

Idris and Matin (1990) stated that number of total tillers hill^{-1} was identical among the six varieties studied.

2.1.1.3 Leaf area index

Swain *et al.* (2006) evaluated in a field experiment the performance of rice hybrids NRH1, NRH3, NRH4, NRH5, PA6111, PA6201, DRRH1, IR64, CR749-20-2 and Lalat conducted in Orissa, India during 1999-2000. Among the hybrids tested, PA 6201 recorded the highest leaf area index.

Roy (1999) reported that in Nizersail, leaf area index peaked around panicle initiation stage and in BRRI dhan 31, although maximum leaf area index was attained at or just before heading stage, the increase of leaf area index from panicle initiation stage to heading stage was only small.

2.1.1.4 Total dry matter production

Amin *et al.* (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (*viz.* Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (*viz.* KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety.

Son *et al.* (1998) reported that dry matter production of four inbred lines of rice (low-tillering large panicle type), YR15965ACP33, YR17104ACP5, YR16510-B-B-B-9, and YR16512-B-B-B-10, and cv. Namcheonbyeo and Daesanbyeo, were evaluated at plant densities of 10 to 300 plants m^{-2} and reported that dry matter production of low-tillering large panicle type rice was lower than that of Namcheonbyeo regardless of plant density.

2.1.2 Effect on yield contributing characters

2.1.2.1 Effective tillers $hill^{-1}$

Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers. They observed that CNHR2 produced more number of productive tillers (413.4 m^{-2}) and filled grains $panicle^{-1}$ (111.0) than other varieties, whereas IR36 gave the highest 1000-grain weight (21.07g) and number of panicles m^{-2} than other tested varieties.

Devaraju *et al.* (1998) reported that the increased yield of KRH2 was mainly attributed due to the higher number of productive tillers $plant^{-1}$.

Chowdhury *et al.* (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. number of productive tillers $hill^{-1}$.

2.1.2.2 Panicle length, filled grains $panicle^{-1}$, unfilled grains $panicle^{-1}$, filled grain percentage, 1000-grain weight

Wang *et al.* (2006) studied the effects of plant density and row spacing (equal row spacing and one seedling $hill^{-1}$, equal row spacing and 3 seedlings $hill^{-1}$, wide-narrow row spacing and one seedling $hill^{-1}$, and wide-narrow row spacing and 3 seedlings $hill^{-1}$ on the yield and yield components of hybrids and conventional cultivars of rice. Compared with conventional cultivars, the

hybrids had larger panicles, heavier seeds, resulting in an average yield increase by 7.27%.

Guilani *et al.* (2003) studied on yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khusestan, Iran. Grain number panicle^{-1} was not significantly different among cultivars. The highest grain number panicle^{-1} was obtained with Anboori. Grain fertility percentages were different among cultivars. Among cultivars, LD183 had the highest grain weight.

Ahmed *et al.* (1997) conducted an experiment to compare the grain yield and yield components of seven modern rice varieties (BR4, BR5, BR10, BR11, BR22, BR23, and BR25) and a local improved variety, Nizersail. The fertilizer dose was 60-60-40 kg ha^{-1} of N, P_2O_5 and K_2O, respectively for all the varieties and found that percent filled grain was the highest in Nizersail followed by BR25 and the lowest in BR11 and BR23.

BRRI (1994) studied the performance of BR14, BR5, Pajam, and Tulsimala and reported that Tulsimala produced the highest number of filled grains panicle^{-1} and BR14 produced the lowest number of filled grains penicle^{-1}.

BINA (1993) evaluated the performance of four varieties IRATOM 24, BR 14, BINA 13 and BINA 19. They found that varieties differed significantly on panicle length and sterile spikelets panicle^{-1}. It was also reported that varieties BINA13 and BINA 19 each had better morphological characters like more grains panicle^{-1} compared to their better parents which contributed to yield improvement in these hybrid lines of rice.

BRRI (1991) reported that the filled grains penicle^{-1} of different modern varieties were 95-100 in BR3, 125 in BR4, 120-130 in BR22 and 110-120 in BR23 when they were cultivated in transplant *aman* season.

Idris and Matin (1990) observed that panicle length differed among the six rice varieties and it was longer in IR20 than in indigenous high yielding varieties.

Singh and Gangwer (1989) conducted an experiment with rice cultivars C-14-8, CR-1009, IET-5656 and IET-6314 and reported that grain number panicle^{-1}, 1000 grain weight were higher for C-14-8 than those of any other three varieties.

Rafey *et al.* (1989) carried out an experiment with three different rice cultivars and reported that weight of 1000 grains differed among the cultivars studied. Shamsuddin *et al.* (1988) observed that panicle number hill^{-1} and 1000-grain weight differed significantly among the varieties.

Costa and Hoque (1986) studied during kharif-II season, 1985 at Tangail FSR site, Palima, Bangladesh with five different varieties of T. *aman* BR4, BR10, BR11, Nizersail and Indrasail. Significant differences were observed in panicle length and number of unfilled grains panicle^{-1} among the tested varieties.

2.1.3 Effect of grain yield and straw yield

Xia *et al.* (2007) found that Shanyou 63 variety gave the higher yield (12 t ha^{-1}) compared to Xieyou46 variety (10 t ha^{-1}).

Swain *et al.* (2006) reported that the control cultivar IR64, with high translocation efficiency and 1000-grain weight and lowest spikelet sterility recorded a grain yield of 5.6 t ha^{-1} that was at par with hybrid PA6201.

Sumit *et al.* (2004) worked with newly released four commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar Dhan 1) and two high yielding cultivars (HYV) as controls (Pant Dhan 4 and Pant Dhan 12) and reported that KHR 2 gave the best yield (7.0 t ha^{-1}) among them.

Dongarwar *et al.* (2003) comprised an experiment to investigate the response of hybrid rice KJTRH-1 in comparison with 2 traditional cultivars, Jaya and Swarna, to 4 fertilizer rates, i.e. 100:50:50, 75:37.5:37.5, 125:62.5:62.5 and 150:75:75 kg NPK ha^{-1} and reported that KJTRH-1 produced significantly higher yield (49.24 q ha^{-1}) than Jaya (39.64 q ha^{-1}) and Swarna (46.06 q ha^{-1}).

Molla (2001) reported that Pro-Agro6201 (hybrid) had a significant higher yield than IET4786 (HYV), due to more mature panicles m^{-2}, higher number of filled grains $panicle^{-1}$ and greater seed weight.

Patel (2000) studied that the varietal performance of Kranti and IR36. He observed that Kranti produced significantly higher grain and straw yield than IR36. The mean yield increased with Kranti over IR36 was 7.1 and 10.0% for grain and straw, respectively.

Julfiquar *et al.* (1998) evaluated 23 hybrids along with three standard checks during *boro* season 1994-95 as preliminary yield trial at Gazipur and it was reported that five hybrids (IR58025A/IR54056, IR54883, PMS8A/IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference.

Rajendra *et al.* (1998) carried out an experiment with hybrid rice cv. Pusa 834 and Pusa HR3 and observed that mean grain yields of Pusa 834 and Pusa HR3 were 3.3 t ha^{-1} and 5.6 t ha^{-1}, respectively.

BRRI (1997) reported that three modern upland rice varieties namely, BR 20, BR 21, BR 24 was suitable for high rainfall belts of Bangladesh. Under proper management, the grain yield was 3.5 ton for BR 20, 3.0 ton for BR 21 and 3.5 ton for BR 24 ha^{-1}.

Nematzadeh *et al.* (1997) reported that local high quality rice cultivars Hassan Sarai and Sang-Tarom were crossed with improved high yielding cultivars Amol 3, PND160-2-1 and RNR1446 in all possible combinations and released

in 1996 under the name Nemat, it gives an average grain yield of 8 t ha^{-1}, twice as much as local cultivars.

BRRI (1995) conducted an experiment to find out varietal performances of BR4, BR10, BR11, BR22, BR23 and BR25 varieties including to local checks Challish and Nizersail produced yields of 4.38, 3.18, 3.12, 3.12 and 2.70 5 t ha^{-1}, respectively.

Chowdhury *et al.* (1995) studied on seven varieties of rice, of which three were native (Maloti, Nizersail and Chandrashail) and four were improved (BR3, BR11, Pasam and Mala). Straw and grain yields were recorded and found that both the grain and straw yields were higher in the improved than the native varieties. Liu (1995) conducted a field trial with new indica hybrid rice II-You 92 and found an average yield of 7.5 t ha^{-1} which was 10% higher than that of standard hybrid Shanyou 64.

In field experiments at Gazipur in 1989-1990 rice cv. BR11 (weakly photosensitive), BR22, BR23 and Nizersail (strongly photosensitive) were sown at various intervals from July to Sept. and transplanted from Aug. to Oct. Among the cv. BR22 gave the highest grain yield from most of the sowing dates in both years (Ali *et al.*, 1993).

Chowdhury *et al.* (1993) also reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e., grain yield and straw yield.

Suprihatno and Sutaryo (1992) conducted an experiment with seven IRRI hybrids and 13 Indonesian hybrids using 1R64 and way-seputih. They observed that TR64 was highest yielding, significantly out yielding IR64616H, IR64618, IR64610H and IR62829A/IR54 which in turn out yielded way-seputih.

Chandra *et al.* (1992) reported that hybrid IR58025A out yielded the IR62829A hybrids and the three control varieties Jaya, IR36 and hybrids IR58025A x 9761-191R and IR58025A IR58025Ax 1R35366-62-1-2-2-3R.

Hossain and Alam (1991) also studied farmers production technology in haor area and found that the grain yield of modern varieties of *boro* rice were 2.12, 2.18, 3.17, 2.27 and 3.05 t ha^{-1}, with BR14, BR11, BR9, IR8 and BR3, respectively.

In evaluation of performance of four HYV and local varieties-BR4, BR16, Rajasail and Kajalsail in *aman* season, BR4 and BR16 were found to produce more grain yield among four varieties (BRRI, 1985).

2.3 Effect of urea fertilizer application method

Deep placement of urea supergranules (USG) has been proven to improve N fertilizer efficiency. In terms of N recovery, agronomical and physiological efficiency, rice varieties utilized N more efficiently when applied as urea (Miah and Ahmed, 2002).

2.3.1 Effect on growth character

2.3.1.1 Plant height

Rahman (2003) observed that plant height did not affected with different level of USG in rice. He carried out an experiment with two levels of urea supergranules (USG) in rice field as 50 and 75 kg N ha^{-1} in *kharif* season. He found that the numerically highest plant height (83 cm) was obtained with 75 kg N ha^{-1} as USG.

Mishra *et al.* (2000) conducted a field experiment in 1994-95 in Bhubaneswar, Orissa, India, and reported that rice cv. Lalate was given 76 kg N ha^{-1} as USG at 0, 7, 14 for 21 days after transplanting (DAT), and these treated control and reported that USG application increased plant height.

Vijaya and Subbaiah (1997) showed that plant height of rice increased with the application of USG and were greater with the deep placement method of application both N and P compared with broadcasting.

On the other hand Rekhi *et al.* (1989) conducted out an experiment on a sandy loamy soil with rice cv. PR106 providing 0, 37.5 or 75 or 112.5 kg N ha^{-1} as 15 N-labeled PU or USG. They noted that application of PU produced the highest plant height.

Singh and Singh (1986) worked with different levels of N as USG, sulphur coated and PU @ 27, 54 and 87 kg ha^{-1}. They reported that deep placement of USG resulted in the highest plant height than PU.

2.3.1.2 Tillering pattern

BRRI (2008a) conducted a comparative study of some promising lines with BRRI modern rice varieties to different N levels *viz*. 0, 30, 60, 90, 120 and 150 kg N ha^{-1}. It was reported that tiller production with N @ 120 kg ha^{-1} produced significantly higher tiller than those of lower N levels.

Mirzeo and Reddy (1989) worked with different modified urea material and levels of N @30, 60 and 90 kg ha^{-1}. They reported that root zone placement of USG produced the highest number of tillers at 30 or 60 days after transplanting.

Singh and Singh (1986) also reported that the number of tillers m^{-2} was significantly greater in USG than PU in all levels of nitrogen.

2.3.1.3 Leaf area index and total dry matter production

Masum *et al.* (2008) conducted an experiment to study the effect of four levels of seedling $hill^{-1}$ *viz* 1, 2, 3 and 4 and two forms of N prilled urea (PU) and urea supergranules (USG) on yield and yield components of modern (BRRI dhan44)

and traditional (Nizershail) transplant *aman* rice. They reported that leaf area index was significantly higher in USG receiving plant than prilled urea.

Amin *et al.* (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (*viz.* Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (*viz.* KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety.

Miah *et al.* (2004) found that LAI was significantly higher in USG receiving plots than urea at heading and the total dry matter production was affected significantly by the forms of N fertilizer. USG applied plots gave higher TDM compared to urea irrespective of number of seedling transplanted $hill^{-1}$. At the same time it also noticed that the difference between treatments for TDM was narrower at early growth stages but became larger in later stages.

Das (1989) reported that the dry matter yield of rice were higher with application of USG.

2.3.2 Effect on yield contributing character

2.3.2.1 Effective tillers $hill^{-1}$

Masum *et al.* (2010) reported that placement of N fertilizer in the form of USG @ 58 kg N ha^{-1} produced the highest number of effective tillers $hill^{-1}$, filled grains $panicle^{-1}$ which ultimately gave the higher grain yield than split application of urea.

A field experiment was conducted by Singh and Shivay (2003) at the Research Farm of the Indian Agricultural Research Institute, New Delhi, India to study the effect of coating prilled urea with eco-friendly neem formulations in improving the efficiency of nitrogen use in hybrid rice. Two rice cultivars, hybrid rice (NDHR-3) and Pusa Basmati-1, formed the main plots, with the levels of N (0, 60, 120 and 180 kg N ha^{-1}) and various forms of urea at 120 kg

N ha^{-1}in the subplots. They found that increasing levels of N significantly increased the number of effective tillers $hill^{-1}$.

Jee and Mahapatra (1989) observed that number of effective tillers m^{-2} were significantly higher with 90 kg N ha^{-1}as deep placed USG than split application of urea.

Rama *et al.* (1989) mentioned that the number of panicles m^{-2} increased significantly when N level increased from 40 to 120 kg N ha^{-1} as different modified urea materials and USG produced significantly higher number of panicles m^{-2} than split application of PU.

Nayak *et al.* (1986) carried out an experiment under rainfed low land conditions with the amount of 58 kg N ha^{-1}as USG placed in root zone. They showed that USG was significantly superior to as sulphur coated urea (SCU) or applying in split dressing, increasing panicle production $unit^{-1}$ area.

2.3.2.2 Panicle length, filled grains $panicle^{-1}$, unfilled grains $panicle^{-1}$, filled grain percentage, 1000 grain weight

Hasanuzzaman *et al.* (2009) conducted an experiment to study the economic and effective method of urea application in rice crop. They noted that urea supergranules produced longest panicle (22.3 cm).

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti and observed that Mukti (5268 kg ha^{-1}) out yielded the other genotypes and recorded the maximum number of filled grains and had lower spikelet sterility (25.85%) compared to the others.

Maitti *et al.* (2003) conducted an experiment to study the effects of N fertilizer rate (0, 120, and 140 kg ha^{-1}) on the performance of 1 cultivar (IET-4786) and 4 hybrid varieties (ProAgro 6Y213, ProAgro 6Y3024, ProAgro 6111N, and ProAgro 6201) of rice in Mohanpur, West Bengal, India. The N fertilizer was

applied during transplanting (50%) and at the tillering and panicle initiation stages (50%). They reported that the application of 140 kg N ha^{-1} resulted in the highest increase in grain yield (by 76.2%), number of panicles (by 109.00%), number of filled grains per panicle (by 26.2%), and 1000-grain weight (5.80%) over the control, and the highest N (136.701 kg ha^{-1}), phosphorus (132.029 kg ha^{-1}), and potassium (135.167 kg ha^{-1}) uptake.

Hasan *et al.* (2002) determined the response of hybrid (Sonar Bangla-1 and Alok 6201) and inbred (BRRI Dhan 34) rice varieties to the application methods of urea supergranules (USG) and prilled urea (PU) and reported that the effect of application method of USG and PU was not significant in respect of panicle length, number of unfilled grains $panicle^{-1}$ and 1000-grains weight.

Ahmed *et al.* (2000) conducted a field experiment to study the effect of point placement of urea supergranules (USG) and broadcasting prilled urea (PU) as sources of N in T. *aman* rice. USG and PU were applied @ 40, 80, 120 or 160 Kg N ha^{-1}. A control treatment was also included in the experiment. They reported that USG was more efficient than PU at all respective levels of nitrogen in producing panicle length, filled grains $panicle^{-1}$ and 1000-grain weight.

Patel and Mishra (1994) carried out an experiment with rice cv. IR36 and were given 0, 30, 60 or 90 kg N ha^{-1} as Muossorie rock phosphate-coated urea, *neem* cake-coated urea and gypsum coated urea, USG or PU. The coated materials as incorporated before transplanting and USG as placed 5-10 cm deep a week after transplanting and urea as applied in 3 split doses. They showed that N management practices had no significant effect on panicle length and percent sterility.

Roy *et al.* (1991) compared deep placement of urea supergranules (USG) by hand and machine and prilled urea (PU) by 2 to 3 split applications in rainfed rice during 1986 and 1987. They reported that USG performed better than PU

in all the parameters tested. Filled grains panicle^{-1} was significantly identical with USG and PU three split treated plots with the highest from PU three split treated plots. Significant difference was observed in 1000-grain weight and highest grain weight was obtained from USG (by hand) treated plots.

Thakur (1991a) observed that yield attributes differed significantly due to levels and sources of N at 60 kg N ha^{-1} through USG produced the highest panicle weight, number of grains panicle^{-1}, 1000- grain weight.

Sen and Pandey (1990) carried out a field trial to study the effects of placement of USG (5, 10 or 15 cm deep) or broadcast PU @ 38.32 kg N ha^{-1} on rice of tall long duration Mashuri and dwarf, short duration Mashuri. They revealed that all depths of USG placement resulted in higher yield characters than broadcast PU; however, differences except for panicle lengths were not significant.

In a field trial, Sarder *et al.* (1988) found that, 94.8 kg N ha^{-1} as basal application of USG gave longer panicle and total number of filled grains penicle^{-1} than the other N sources.

2.3.3 Effect of grain yield and straw yield

Hasanuzzaman *et al.* (2009) conducted research on different urea application treatments (200 kg ha^{-1} at urea two equal splits, ½ during final land preparation + ½ at 30 DAT, (200 kg ha^{-1} urea at three equal splits; $^{1/2}$ during final land preparation + $^{1/2}$ at 30 DAT + / at 55 DAT; Urea supergranules (USG) @ 50 kg ha^{-1}; Urea supergranules @ 75 kg ha^{-1}; 0.5% foliar spray @ 20 kg ha^{-1}; 1% foliar spray @ 40 kg ha^{-1}. Both the growth and yield was significantly affected by different methods of urea application. In all of the case except plant height and straw yield Urea supergranules @ 75 kg ha^{-1} gave the highest result.

Kabir *et al.* (2009) conducted an experiment to find out the effect of urea super granules (USG), prilled urea (PU) and poultry manure (PM) on the yield and yield contributes of transplant *aman* rice. They observed that the highest grain

yield (5.17 t ha^{-1}), straw yield (6.13 t ha^{-1}) and harvest index (46.78%) were found from full dose of USG.

BRRI (2009) conducted an experiment on study of N release pattern from USG and prilled urea under field condition and its effect on grain yield and N nutrition of rice with three doses of N namely 50, 100 and 150 kg N ha^{-1} from two types of urea e.g. prilled (PU) and urea super granules (USG) were tested as treatment. Result showed that the highest grain yield was recorded when N applied @ 100 kg N ha^{-1} both from USG and PU and the highest straw yield was obtained in PU @ 150 kg N ha^{-1}.

BRRI (2008 b) conducted an experiment on the title of response of MVs and hybrid entries to added N in a rice rice cropping pattern. Six N doses 0, 40, 80, 120, 160 and 120 kg N ha^{-1} were tested and resulted that grain yield of hybrid responded up to 120 kg N ha^{-1}.

A field experiment was conducted by Rakesh *et al.* (2005) at Research farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India, to determine the response of hybrid rice cv. MPH-501 to different nitrogen (40, 80, 120 and 160 kg N ha^{-1}) and potassium levels (30, 60, and 90 kg K_2O ha^{-1}). The application of 160 kg N and 60 kg K_2O ha^{-1} significantly influenced the growth and yield attributes of hybrid rice and produced higher grain and straw yield.

Edwin and Krishnarajan (2005) reported that N supplied at 7 DAT, 21 DAT, panicle initiation stage and first flowering stage gave the highest grain yield and straw yield and lowest level of spikelet sterility (25.30%).

Alam (2002) found that plant height and tiller number increase significantly with the increased level of USG/4 hill. They also reported that growth and yield parameters were increased with the increased level of N from 27-87 kg N ha^{-1}. Deep placement of urea supergranules (USG) resulted in the highest plant

height, tillers hill^{-1}, biological yield, grain yield and harvest index than prilled urea.

Ahmed *et al.* (2000) also revealed that USG was more efficient than PU at all respective levels of nitrogen in producing all yield components and in turn, grain and straw yields. Placement of USG @ 160 Kg N ha^{-1}produced the highest grain yield (4.32 t ha^{-1}) which was statistically identical to that obtained from 120 kg N ha^{-1} as USG and significantly superior to that obtained from any other level and source of N.

Jaiswal and Singh (2001) carried out a field experiment on the comparative efficiency of urea supergranules and prilled urea, both at 60 and 120 kg ha^{-1} on rice cultivation under different planting method during 1996-97 and 1997-98, in Faizabad, Uttar Pradesh, India. They stated that transplanting method with USG placement proved to be best for maximum grain yield (4.53 t ha^{-1}) and deep placement of USG increased N use efficiency (31.7%) compared to conventionally applied urea.

Mishra *et al.* (1999) conducted a field experiment with urea supergranules (USG) in wet land rice (*Oryza sativa* cv. Lalat) in affine textured soil. USG was applied at 76 kg N ha^{-1} along with prilled urea (PU) split. They found that placement of USG significantly increased both the grain and straw yield of rice compared to PU. Rice showed a greater response to N upon USG placement than split application of PU.

Balaswamy (1999) found that deep placement of nitrogen as urea supergranules reduced the dry weight of weeds resulting in more panicles and filled grains and increased the grain yield of rice over the split application of prilled urea by 0.43 and 0.3 t ha^{-1} and basal application of large granular urea by 0.73 and 0.64 t ha^{-1} in 1985 and 1986, respectively.

Detailed results of the experiments conducted at BRRI during the period from 1975-1985 on USG were presented in a technical session on fertilizer N deep placement for rice. The recommendation made in that technical session showed that deep placement of urea for rice was superior to split broadcast application during the dry season and the economics of use appeared favorable. But inconsistent results during wet seasons indicate further research is needed. The economic benefit of USG relative to PU was very high during the *boro* season than the transplant *aman* season. However, the benefit was higher in a lower rate of USG application in both seasons (Bhuiyan *et al.*, 1998).

Department of Agricultural Extension conducted 432 demonstrations in 72 Upazilla as of 31 districts in Bangladesh of *boro* rice. It was reported that USG plots, on an average, produced nearly 5 percent higher yields than the PU treated plots while applying 30-40% less urea in the form of USG (Islam and Black, 1998).

Singh and Singh (1997) conducted a field experiment in 1987 in Uttar Pradesh, India, dwarf rice cv. Jaya was given 90 or 120 kg N ha^{-1} as urea super granules, large granular urea or neem cake coated urea. N was applied basally, or in 2 equal splits (basally and panicle initiation). They found that grain yield was highest with 120 kg N (4.65 t ha^{-1}), was not affected by N source and was higher with split application.

Kumar *et al.* (1996) reported that application of USG in the sub soil gave 22% higher grain yield than control. Pandey and Tiwari (1996) conducted a field trial in 1990-91 at Rewa, Madhya Pradesh , rice was given 87 kg N ha^{-1} as a basal application of urea super granules (USG), prilled urea (PU), Mussoorie rock phosphate urea (MRPU), large granular urea (LGU) or nimin [neem seed extract]-coated urea (NCU) or PU, MRPU, LGU and NCU as 66% basal incorporation + 33% top dressing at panicle initiation and found that grain yield was highest with N applied as a basal application of USG or MRPU applied in 2 split applications.

Rashid *et al.* (1996) conducted field experiments in two locations of Gazipur district during *boro* season (Jan-May) of 1989 to determine the N use efficiency of urea supergranules (USG) and prilled urea (PU) irrigated rice cultivation. It was observed that 87 kg N ha^{-1} from USG produced the highest grain yield. However, 58 kg N ha^{-1} from USG and 87 kg N ha^{-1} from PU produced statistically similar grain yield to that of 87 kg ha^{-1} from USG.

Bastia and Sarker (1995) conducted a field trial in Kharif seasons with rice cv. Jagnnath was given lac-coated urea and observed that grain yield and N content were 4.07 t ha^{-1} and 1.43%, respectively with USG and the lowest 2.66 t ha^{-1} and 1.31% with PU.

Dweivedi and Bajpai (1995) observed through using 0 to 90 kg N ha^{-1} as urea, USG + urea or urea spray and they found that grain yield and net returns increased with the increased rate of N application and were highest with USG and lowest with urea spray.

Harun *et al.* (1995) studied in the farmer's fields at the BRRI project area, Gazipur during the *boro* seasons of 1988-89 and 1989-90 to compare of urea supergranules (USG) and prilled urea (PU) application in irrigated rice. Nitrogenous fertilizers were applied at the rate of 29, 58 and 87 kg ha^{-1}, separately, from USG and PU. The performance of USG was found better than that of PU in relation to grain yield.

Surendra *et al.* (1995) conducted an experiment during rainy season with nitrogen level @ 0, 40, 80, 120 kg ha^{-1} and sources of N, USG and urea dicyandiamide @ 80 ka ha^{-1}. They showed that USG and urea dicyandiamide produced significantly more panicles grains $panicle^{-1}$, panicle weight and grain yield than PU @ 80 kg N ha^{-1}.

Swain *et al.* (1995) evaluated the performance of USG application methods in low land transplanted rice. He reported that USG gave higher grain and straw yield.

Das and Singh (1994) pointed out the grain yield of rice cv. RTH-2 during Kharif season was greater for deep placed USG than USG for broadcast and incorporated or three split applications of PU.

Mishra *et al.* (1994) conducted a field trial with rice cv. Sita giving 0 or 80kg N ha^{-1} as urea, urea supergranules, *neem* coated urea. They reported that the highest grain yield was obtained by urea in three split applications (3.39 t ha^{-1}).

Quayum and Prasad (1994) conducted field trials during Kharif season with 5 rates of N (0, 37.5, 75, 112.5 and 150 kg ha^{-1}) and six different sources of N with rice cv. Sita and found that application of up to 112.5 kg N ha^{-1} increased grain (4.37 t ha^{-1}) and straw yields (5.49 t ha^{-1}). They also reported that N applied as USG gave the best yield and concluded that slow release fertilizers were effective for rainfed lowland rice.

Bhale and Salunke (1993) conducted a field trial to study the response of upland irrigated rice to nitrogen applied through urea and USG. They found that grain yield increased with up to 120 kg urea and 100 kg USG.

Bhardwaj and Singh (1993) observed that placement of 84 kg N as USG produced a grain yield t ha^{-1} which was similar to placing 112 kg USG and significantly greater than N sources and rates.

Budhar and Palaniappan (1993) compared the performance of 30 or 60 kg N ha^{-1} as PU, lac-coated urea or USG applied as basal, split or deep placement in Jalmagna rice. They reported that grain yield and N uptake increased with the rate of N application and was highest with deep placement USG. They also

reported that N use efficiency was highest with 30 kg N ha^{-1} as deep placement of USG.

Harun *et al.* (1993) compared the benefits of USG application over PU and they found that USG produced at least 25% higher yield than PU and the marginal rate of return highest for USG at 58 kg N ha^{-1}.

Singh *et al.* (1993) pointed out that application of 30 or 60 kg N ha^{-1} as PU or USG gave the highest grain yield and N uptake increase with the rate of N application and were highest with deep placed USG. N use efficiency was the highest with 30 kg N ha^{-1} from deep placed USG.

Zaman *et al.* (1993) conducted two experiments on a coastal saline soil at the Bangladesh Rice Research Institute (BRRI), Regional station, Sonagazi in 1988 and 1989 *aus* seasons to compare the efficiencies of prilled urea (PU) and urea supergranules (USG) as sources of N for upland rice. The N doses used as treatments were 29 kg ha^{-1} and 58 Kg ha^{-1} for both PU and USG. The test variety was BR20. They found that USG consistently produced significantly higher grain yield and straw yield than PU.

Bhagat *et al.* (1992) conducted a field experiment with rice cv. IR 36 and was given 56 kg N ha^{-1} as prilled urea, large granule urea or urea supergranules or 84 kg N as prilled urea produced mean grain yields of 2.15, 2.18, 2.25, 2.58 and 2.72 t ha^{-1}, respectively, compared with the control (given no N) yield of 1.48 t ha^{-1}. They reported that the relative N use efficiency was the highest from the application of 84 kg N as prilled urea.

Johnkutty and Mathew (1992) conducted an experiment with different forms of nitrogen on rice cv. Jyothy during rainy season and reported that 84 kg N ha^{-1} USG gave higher yield than PU.

Sahu *et al.* (1991) worked on the method of application of USG in low land rice soil and showed that USG gave higher yields than PU when USG was placed at midway between at every alternate 4 hills.

Satrusajong *et al.* (1991) conducted a field experiment to study the effect of N and S fertilizers on yields of rainfed low land rice. They found that rice yield was statistically greater for deep placement of urea as USG than all other N fertilizer treatments that included PU, urea amended with increase inhibitor and ammonium phosphate sulfate (16% N, 8.6% P).

Thakur (1991b) carried out an experiment in 1986 on silty loam soil. The effect of N @ 0, 30 or 60 kg ha^{-1} as PU, USG or urea briquettes were evaluated on yield and N use efficiency of rice cv. IET 7599, IET 7300, IET 6903 and Pankaj, he reported that USG gave highest grain yield and N use efficiency of 19.0 kg $grains^{-1}$ kg N.

Singh *et al.* (1991) studied the effect of sources and level of N on the yield, yield attributes and N uptake of rice and reported that yield was affected significantly due to sources and levels of N. Deep placement of USG showed the highest grain yield (2.59 t ha^{-1}) followed by 2.43, 2.32 and 2.15 t ha^{-1} with sulphur coated urea, Mussoorie rock phosphate-coated urea and PU, respectively.

The USG @ 75 kg N ha^{-1} gave grain yield of 5.22 t ha^{-1} whereas prilled urea gave only 4.29 t ha^{-1} with the same rate. Uptake and use efficiency of N were also higher with USG compared to prilled urea (Chakraborti *et al.*, 1989).

Chauhan and Mishra (1989) found that application of N@ 20, 80, 120 kg ha^{-1} as USG gave grain yield 4.08, 4.86 and 5.17 t ha^{-1} and as PU gave 3.95, 3.72 and 4.33 t ha^{-1}, respectively. Deep placement of USG proved superior to PU.

Mirzeo and Reddy (1989) also reported that deep placement of USG gave 10.3% more grain yield than PU or *neem* coated urea. The straw yields also the highest with USG.

Mohanty *et al.* (1989) observed that placement of USG in rice gave significantly higher grain and straw yields of 36 and 39% in dry and 17 and 18% in wet season, respectively than split application of PU.

Sahu and Mitra (1989) reported that higher grain yields were obtained with large granular urea @ 60 or 90 kg N ha^{-1} applied in two splits (7 days after transplanting and panicle initiation stage) than with PU. USG gave higher yields than large granular urea or PU.

Lal *et al.* (1988) reported that placement of N as USG and broadcast incorporation of SCU were superior to PU (applied in three split surface dressings) at 29, 58 and 87 kg N ha^{-1} but not at 116 kg N ha^{-1}. SCU gave the highest grain yield followed by USG and both maintained superiority over PU up to 87 kg N ha^{-1}.

Zia *et al.* (1988) reported that urea in three split applications produced the maximum rice yield followed by SCU, USG, UNS.

Raju *et al.* (1987) conducted an experiment with different sources of N fertilizers @ 0, 37.5, 75, 112.5 and 150 kg N ha^{-1}. They reported that among all the sources of N, USG recorded highest grain yield (5.4 t ha^{-1}) and proved significantly superior to rest of the sources. The increase in yield due to USG over urea application was to the turn of 14.7%. The rest of N sources failed to exert any differential effect on yield.

Setty *et al.* (1987) evaluated different levels of modified urea on rice as USG and sulphur coated urea. They observed that grain yield increased significantly with increase N rate up to 87 kg ha^{-1}. Sulphur coated urea and USG gave

similar yields, which were significantly higher than urea in 2-3 split application. N use efficiency was greater with sulphur coated and USG than urea.

Tomar (1987) investigated that split applications of PU, sulphur coated urea (SCU), Mussorie phos-coated urea (MPCU) and USG @ 58, 87 or 116 kg N ha^{-1} of rice in Kharif season gave higher grain yield from USG and SCU @ 87 kg N ha^{-1} than other two forms of urea.

Patel and Chandrawansi (1986) conducted an experiment with rice cv. Sumridhi (R-23.84) giving without N, or with 40 kg N ha^{-1} as urea broadcast and incorporated as a basal dose before sowing USG applied in furrows and seeds drilled in alternate rows, urea or USG and seed drilled in the same furrow. They reported that the treatments did not significantly affect the number of panicles m^{-2} but yield was highest (2.4 t ha^{-1}) in the last of the above treatments.

Reddy *et al.* (1986) reported that N as USG placed in the root zone in soil gave significantly higher yields than N as *neem* cake coated urea, Dicyandiamide incorporated urea mixed with moist soil or urea.

Ali (1985) carried out a field trial with rice cv. BR3 growing on gray flood plain and red brown terrace soils applying N as PU, USG or SCU, immediately before or after transplanting or in 2-3 splits. It was reported that deep point placement of USG was superior to 2 or 3 applications of PU on both soils. The superiority of USG was more pronounced in *boro* than in *aus* season or T. *aman* season. USG was superior at all N rates; 62 kg N ha^{-1} regardless of management. SCU produced the lowest yield at both sites.

Manickam and Ramaswami (1985) stated that the highest grain yield varying from 3.4 to 4.6 t ha^{-1}, were obtained with USG and followed by PPDU and PU. Roy (1985) concluded that point placement of urea in mud balls or as USG

could increase efficiency of N utilization by rice and increase yield in wet season. Sen *et al.* (1985) reported that the average increase in yield from USG placement compared with urea alone in three splits dressing was about 46% (in 1982 and 20% (in 1983). All yield components were positively correlated with yield.

Chapter 3

Materials and Methods

MATERIALS AND METHODS

Details of different materials used and methodologies followed in the experiment are presented in this chapter.

3.1 Description of the experimental site

3.1 Location

The field experiment was conducted at Agronomy field laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from July to December, 2010. The location of the experimental site has been shown in Appendix I.

3.2 Soil

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It was a medium high land with non-calcarious dark grey soil. The pH value of the soil was 5.6. The characteristics of the experimental soil have been shown in Appendix II.

3.3 Climate

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from October to March. The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the Dhaka meteorology centre, Dhaka for the period of experimentation have been presented in Appendix III.

3.4 Plant materials and features

Rice cv. BR11, BRRI dhan 33, BRRI dhan 39 and BRRI dhan 46 were used as plant materials for the present study. These varieties are recommended for aman season.

3.5 Experimental details

There were 16 treatment combinations. The total numbers of unit plots were 48. The size of unit plot was 3 m × 2.5 m (7.5 m^2). The distances between plot to plot and replication to replication were 1 m.

3.5.1 Treatments

The experiment consisted of two factors as mentioned below:

Factor A: Different methods of urea application

N_1 = 15 kg N ha^{-1} as prilled urea at final land preparation + 15 kg N ha^{-1} as prilled urea at 30 DAT+ 15 kg N ha^{-1} as prilled urea 50 DAT

N_2= 15 kg N ha^{-1} as prilled urea at 7 DAT + 15 kg N ha^{-1} as prilled urea at 30 DAT + 15 kg N ha^{-1} as prilled urea at 50 DAT

N_3= 60 kg N ha^{-1} USG (1.8 g) at 7 DAT

N_4= 15 kg N ha^{-1} as prilled urea at 15 DAT+ 15 kg N ha^{-1} as prilled urea 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT

Factor B: Variety

V_1 = BR11

V_2 = BRRI dhan33

V_3= BRRI dhan39

V_4 = BRRI dhan46

Replication :3

3.5.2 Experimental design

The experiment was laid out in a split-plot design with three replications having different methods of urea application in main plots and variety in the sub-plot.

3.6 Growing of crops

3.6.1 Raising seedlings

3.6.1.1 Seed collection

The seeds of the test crop i.e. BR11, BRRI dhan33, BRRI dhan39 and BRRI dhan46 were collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur

3.6.1.2 Seed sprouting

Healthy seeds were selected by specific gravity method and then immersed in water bucket for 24 hours and then it was kept tightly in gunny bags. The seeds started sprouting after 48 hours and were sown in nursery bed after 72 hours.

3.6.1.3 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on July 10, 2010 in order to transplant the seedlings in the main field.

3.6.2 Preparation of the main field

The selected plot for the experiment was opened on 26 July 2010 with a power tiller, and exposed to the sun for a week, there after the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good puddle condition. Weeds and stubble were removed, and finally obtained a desirable puddled condition of soil for transplanting of seedlings.

3.6.3 Fertilizers and manure application

The fertilizers P, K, S and Zn in the form of TSP, MoP, Gypsum and $ZnSO_4$, respectively were applied. The entire amount of TSP, MoP, Gypsum and Zinc sulphate at rate of 100 kg ha^{-1}, 70 kg ha^{-1}, 60 kg ha^{-1} and 10 kg ha^{-1} respectively were applied during the final land preparation. Nitrogenous fertilizer was applied as per treatment.

3.6.4 Uprooting seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on August 07, 2010 without causing much mechanical injury to the roots.

3.6.5 Transplanting of seedlings in the field

The twenty eight days old seedlings were transplanted in the main field on August 08, 2010 and the rice seedlings were transplanted in lines each having a line to line distance of 25 cm and plant to plant distance was 15 cm for all treat varieties in the well prepared plot.

3.6.6 Cultural operations

The details of different cultural operations performed during the course of experimentation are given below:

3.6.6.1 Irrigation and drainage

The experimental plots required two irrigations during the crop growth season and sometimes drainages were done at the time of heavy rainfall.

3.6.6.2 Gap filling

Gap filling was done for all of the plots at 7-10 days after transplanting (DAT) by planting same aged seedlings.

3.6.6.3 Weeding

Weeding was done from each plot at 25 and 45 DAT. Hand weeding was done from each plot.

3.6.6.4 Plant protection

There were negligible infestations of insect-pests during the crop growth period. Yet to keep the crop growth in normal, Basudin was applied at tillering stage @ 17 kg ha $^{-1}$ while Diazinon 60 EC @ 850 ml ha^{-1} were applied to control stem borer and rice bug respectively.

3.7 Harvesting, threshing and cleaning

The maturity of crop was determined when 85% to 90% of the grains become golden yellow in colour. The crop was harvested plot wise at maturity by cutting the whole plants at the ground level with sickle. The harvested crop of each plot was bundled separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in sun. Before harvesting, ten hills were selected randomly for each plot and cut at the ground level for collecting data on yield contributing characters.

Variety	Harvesting date
BR11	November 16, 2010
BRRI dhan33	October 15, 2010
BRRI dhan39	November 16, 2010
BRRI dhan46	November 16, 2010

3.8. General observations

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants which were vigorous and luxuriant in the treatment plots than that of control plots.

3.8.1 Detecting the flowering stage (50%) and observation of heading

With experience, it was felt that identifying the flowering stage should need to follow regular field observations as flowering date (50%) were recorded after visual observations. Therefore, Regular observations were made accordingly.

3.9 Data recording

The following data were collected during the study period:

3.9.1 Growth parameters

1. Plant height (cm)
2. Number of tillers hill^{-1}
3. Number of leaves hill^{-1}
4. Leaf area index

3.9.2 Yield and yield contributing parameters

1. Panicle length (cm)
2. Grains panicle^{-1}
3. Weight of 1000 grain (g)
4. Grain yield (t ha^{-1})
5. Straw yield (t ha^{-1})
6. Biological yield (t ha^{-1})
7. Harvest index (%)

3.9.3 Procedure of recording data

3.9.3.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 15, 30, 45, 60 DAT (days after transplanting) and at harvest. Data were recorded from the average of same 10 random preselected plants at the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

3.9.3.2 Number of tillers hill^{-1}

The number of tillers hill^{-1} was recorded at 15, 30, 45, 60 DAT and at harvest by counting total tillers as the average of same 5 hills selected at random from the inner rows of each plot.

3.9.3.3 Number of leaves hill^{-1}

The number of leaves hill^{-1} was recorded at 15, 30, 45, 60 DAT and at harvest by counting total tillers as the average of same 5 hills selected at random from the inner rows of each plot.

3.9.3.4 Leaf area index

Leaf area index was estimated manually measuring the length and width of leaf and multiplying by a factor 0.75 as suggested by Yoshida (1981).

3.9.3.5 Panicle length

The length of panicle was measured with a meter scale from 10 selected panicles and the average value was recorded.

3.9.3.6 Grains panicle^{-1}

The total number of grains was collected randomly from selected 10 panicles of a plot and then average number of grains panicle^{-1} was calculated.

3.9.3.7 1000-grain weight

One thousand grains were counted randomly from the total cleaned harvested grains of each individual plot and then weighed in grams and recorded.

3.9.3.8 Grain yield

Grains obtained from demarked area of each unit plot were sun-dried and weighed carefully and finally converted to t ha^{-1}. The central 4 m^2 from each plot were harvested, threshed, dried, cleaned and weighed.

3.9.3.9 Straw yield

Straw obtained from each treatment were sun-dried and weighed carefully and finally converted to t ha^{-1}. The dry weight of straw of central 4 m^2 were harvested, threshed, dried and weighed

3.9.3.10 Biological yield

Grain yield and straw yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Straw yield.

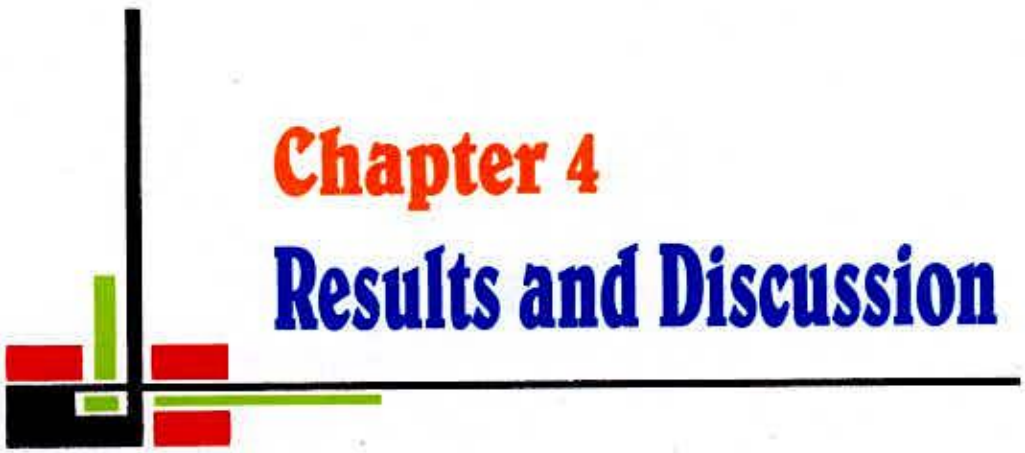
3.9.3.11 Harvest index

Harvest index was calculated from the grain and straw yield of rice from each treatment and expressed in percentage.

$$HI\ (\%) = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (grain weight + straw weight)}} \times 100$$

3.10 Statistical Analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques using MSTAT-C package and the mean values were separated using least significant differences (LSD) test at 5% level of significance.



Chapter 4

Results and Discussion

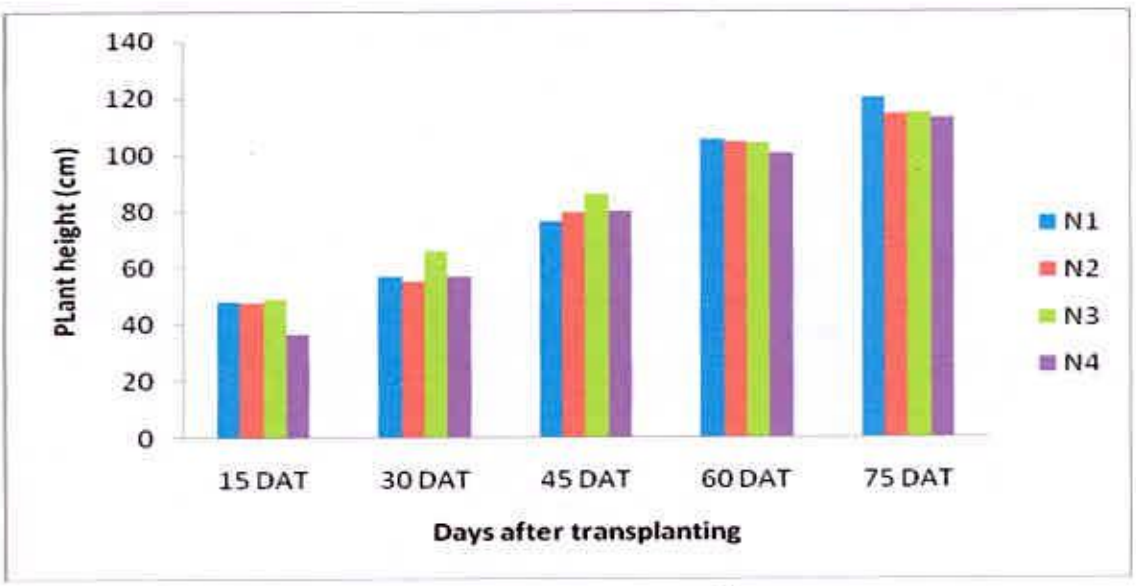
RESULTS AND DISCUSSIONS

4.1 Growth parameters

4.1.1 Plant height

4.1.1.1 Effect of urea fertilizer application method

Statistically significant variation was observed on plant height at 15, 30 and 45 DAT but insignificant at 60 and 75 DAT for different N fertilizer application method (Figure 1). The longest plant at 15 DAT (48.77 cm), 30 DAT (65.44 cm) and 45 DAT (86.25 cm) were recorded for application of 1.8 g USG at 7 DAT. Application of recommended prilled urea @ 1/3 at 15 DAT+ 1/3 at 30 DAT + 1/3 at 50 DAT produced the shortest plant at 60 DAT (100.34 cm) and 75 DAT (113.00 cm); on the other hand application of recommended amount urea as 1/3 at final land preparation+ 1/3 at 30 DAT + 1/3 at 50 DAT produced the longest plant at 60 DAT (105.18 cm) and 75 DAT (120.10 cm). This result was also in agreement with the findings of Vijaya and Subbaiah (1997) who showed that plant height of rice increased with the application of USG.



N_1 = 15 kgN ha^{-1} as prilled urea at final land preparation + 15 kg N ha^{-1} as prilled urea at 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT

N_2= 15 kg N ha^{-1} as prilled urea at 7 DAT + 15 kg N ha^{-1} as prilled urea at 30 DAT + 15 kg N ha^{-1} as prilled urea at 50 DAT

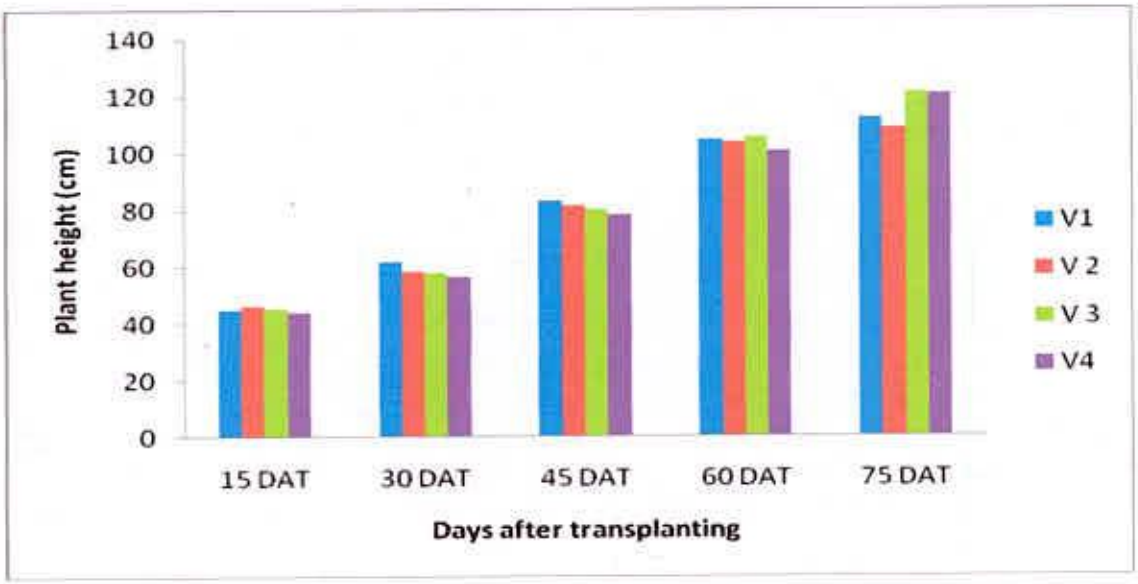
N_3= 60 kg ha^{-1} USG at 7 DAT

N_4= 15 kg N ha^{-1} as prilled urea at 15 DAT+ 15 kg N ha^{-1} as prilled urea 30 DAT+ 15 kgN ha^{-1} as prilled urea at 50 DAT

Figure 1. Effect of urea fertilizer application method on plant height of *aman* rice [$LSD_{(0.05)}$ = 5.163, 6.425, 7.297, NS, 8.074]

4.1.1.2 Effect of variety

There were no significant variations observed in plant height at 15 DAT, 30 DAT, 45 DAT and 60 DAT for variety but significant at 75 DAT (Figure 2). The longest plant at 75 DAT (120.83 cm) was observed from BRRI dhan39 which was statistically similar with BRRI dhan46. The shortest plant at 15 DAT to 60 DAT was recorded from variety BRRI dhan46. Dissimilar results also by Bisne *et al.* (2006) who showed that plant height differed significantly among the varieties.



V_1 = BR11 V_2 = BRRI dhan33 V_3= BRRI dhan39 V_4 = BRRI dhan46

Figure 2. Effect of variety on plant height of *aman* rice [$LSD_{(0.05)}$ = NS, NS, NS, NS, 8.074]

4.1.1.3 Combined effect of urea fertilizer application method and variety

Variations in plant height at 15, 30, 45 and 75 DAT was significant but insignificant at 60 DAT for interaction effect of N fertilizer application method and variety (Table 1). The longest plant at 30 DAT (72.69 cm) and 45 DAT (90.55 cm) was recorded from $N_3 \times V_1$ interaction. At 75 DAT (127.67 cm), $N_1 \times V_3$ combination showed the longest plant which was statistically similar for all other interaction except $N_4 \times V_1$ and $N_4 \times V_2$. Combination of 1/3 urea at 15

DAT+1/3 urea at 30 DAT+ 1/3 urea at 50 DAT with BR11 (103.33 am) and BRRI dhan33 (105.00 cm) showed the shortest plant at 75 DAT.

Table 1. Combined effect of urea fertilizer application method and variety on plant height of *aman* rice

Treatments	Plant height (cm)				
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
$N_1 \times V_1$	47.26 ab	50.85 cd	73.04 b	104.21	119.67 ab
$N_1 \times V_2$	50.49 ab	53.0 bcd	69.51 b	109.26	110.67 ab
$N_1 \times V_3$	49.64 ab	65.59 abc	82.41 ab	111.08	127.67 a
$N_1 \times V_4$	42.55 a-c	56.48 bcd	79.52 ab	96.17	122.33 ab
$N_2 \times V_1$	47.64 ab	59.73 abc	86.60 ab	116.56	115.33 ab
$N_2 \times V_2$	49.04 ab	62.0 abc	80.29 ab	103.61	109.00 ab
$N_2 \times V_3$	47.48 ab	52.73 bcd	75.14 ab	103.61	120.00 ab
$N_2 \times V_4$	44.13 a-c	44.59 d	75.20 ab	93.48	112.33 ab
$N_3 \times V_1$	50.35 ab	72.69 a	90.55 a	99.43	109.67 ab
$N_3 \times V_2$	51.88 a	66.22 ab	90.36 a	100.72	108.67 ab
$N_3 \times V_3$	44.10 a-c	56.98 b-d	81.59 ab	106.63	114.33 ab
$N_3 \times V_4$	48.74 ab	65.86 a-c	82.50 ab	108.07	125.00 a
$N_4 \times V_1$	33.25 c	62.38 a-c	81.86 ab	97.32	103.33 b
$N_4 \times V_2$	33.10 c	50.90 cd	84.03 ab	100.64	105.00 b
$N_4 \times V_3$	39.03 bc	55.14 b-d	79.49 ab	99.69	121.33 ab
$N_4 \times V_4$	39.74 a-c	58.52 a-d	74.12 ab	103.91	122.33 ab
CV (%)	13.50	9.73	10.77	NS	8.30
$LSD_{(0.05)}$	10.33	12.85	14.59	20.07	16.15

V_1 = BR11 V_2 = BRRI dhan33 V_3= BRRI dhan39 V_4 = BRRI dhan46

N_1 = 15 kgN ha^{-1} as prilled urea at final land preparation + 15 kg N ha^{-1} as prilled urea at 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT

N_2= 15 kg N ha^{-1} as prilled urea at 7 DAT + 15 kg N ha^{-1} as prilled urea at 30 DAT + 15 kg N ha^{-1} as prilled urea at 50 DAT

N_3= 60 kg ha^{-1} USG at 7 DAT

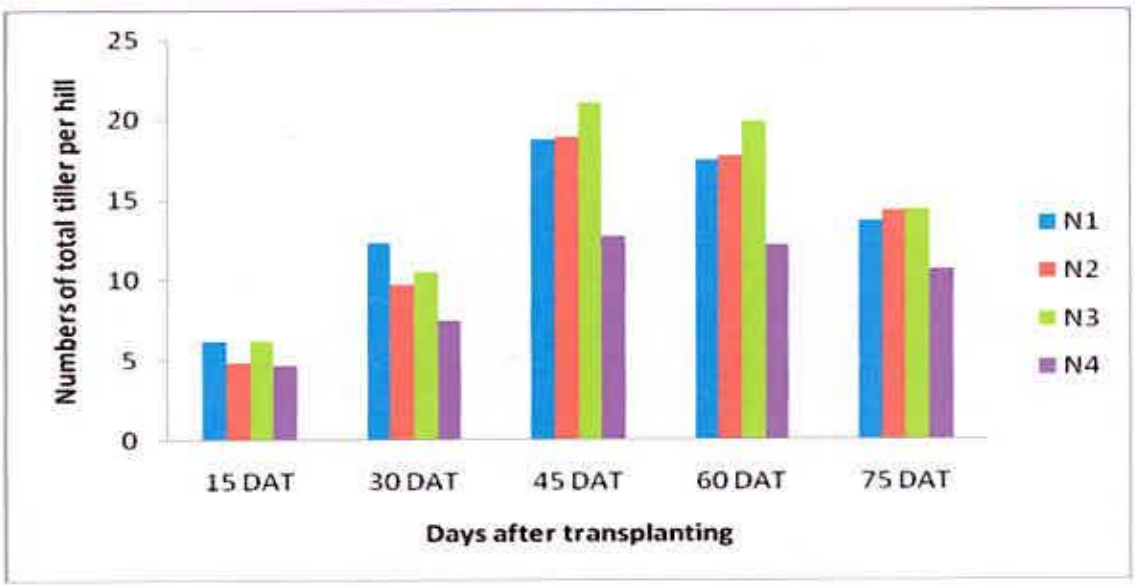
N_4= 15 kg N ha^{-1} as prilled urea at 15 DAT+ 15 kg N ha^{-1} as prilled urea 30 DAT+ 15 kgN ha^{-1} as prilled urea at 50 DAT

4.1.2 Tillering pattern

4.1.2.1 Urea fertilizer application method

Significant variations were observed for different nitrogen fertilizer application method on tillering pattern of aman rice through all over their growth period (Figure 3). Application of 1.8 g USG at 7 DAT produced the maximum tiller at 45 DAT (21.00), 60 DAT (19.83) and 75 DAT (14.33), which were statistically similar with other nitrogen fertilizer application method except N_4. The minimum number of tiller at 15 DAT (4.58), 30 DAT (7.38), 45 DAT (12.67),

60 DAT (12.08) and 75 DAT (10.58) were recorded for application of recommended amount of prilled urea @ 1/3 at15 DAT+ 1/3 at 30 DAT+ 1/3 at 50 DAT. This result also in agreement with the findings of Singh and Singh (1986) who reported that the number of tillers m^{-2} was significantly greater in USG than PU in all levels of nitrogen.



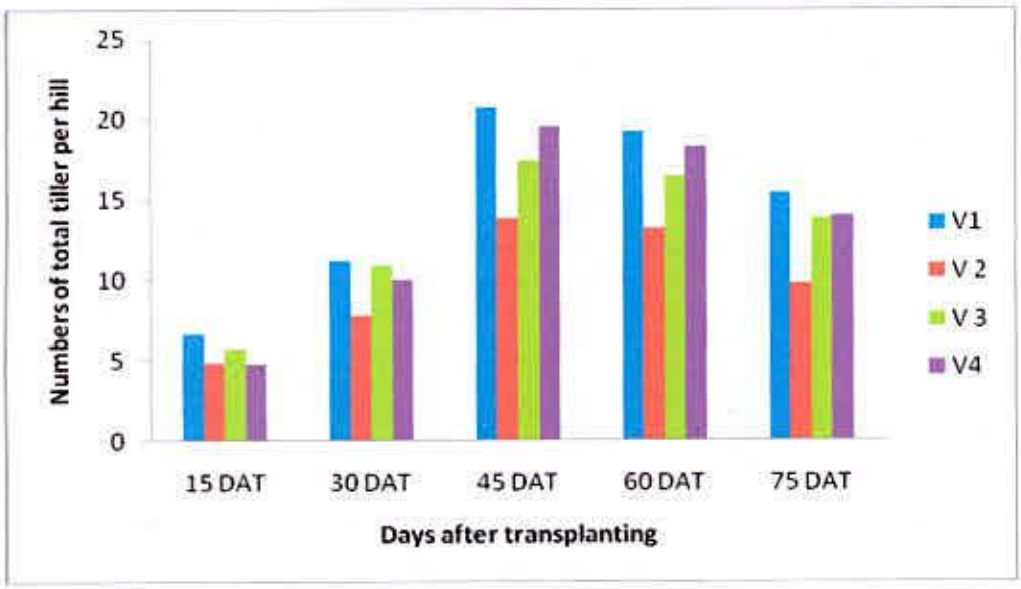
N_1 = 15 kgN ha^{-1} as prilled urea at final land preparation + 15 kg N ha^{-1} as prilled urea at 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT
N_2= 15 kg N ha^{-1} as prilled urea at 7 DAT + 15 kg N ha^{-1} as prilled urea at 30 DAT + 15 kg N ha^{-1} as prilled urea at 50 DAT
N_3= 60 kg ha^{-1} USG at 7 DAT
N_4= 15 kg N ha^{-1} as prilled urea at 15 DAT+ 15 kg N ha^{-1} as prilled urea 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT

Figure 3. Effect of urea fertilizer application method on tillering pattern of *aman* rice [$LSD_{(0.05)}$ = 1.236, 2.174, 2.947, 2.634, 2.547]

4.1.2.2 Effect of variety

There were significant variations observed on tillering pattern for variety (Figure 4). The maximum number of tillers at 15 DAT (6.58), 30 DAT (11.17), 45 DAT (20.67), 60 DAT (19.17) and 75 DAT (15.33) were recorded from the variety BR11. At 30, 60 and 75 DAT statistically similar number of tillers also showed by BRRI dhan39 and BRRI dhan46. BRRI dhan 33 showed the minimum number of tillers at 30 DAT (7.75), 45 DAT (13.75), 60 DAT (13.17) and 75 DAT (9.75). This result was in agreement with the findings of Bisne *et al.* (2006) who conducted an experiment with eight promising varieties using

four CMS lines and showed that tiller number hill^{-1} and grain yield differed significantly among the varieties.



V_1 = BR11 V_2 = BRRI dhan33 V_3= BRRIdhan39 V_4 = BRRI dhan46

Figure 4. Effect of variety on tillering pattern of aman rice
[LSD $_{(0.05)}$= 1.236, 2.174, 2.947, 2.634, 2.547]

4.1.2.3 Combined effect of urea fertilizer application method and variety

Statistically significant variation observed for combined effect of urea fertilizer application method and variety on tillering pattern throughout the growth period of aman rice (Table 2). The maximum number of tillers at 15 DAT (8.67) and 30 DAT (15) were recorded from the combination of urea fertilizer application as 1/3 at final land preparation+ 1/3 at 30 DAT + 1/3 at 50 DAT and variety BR11. Combination of 1.8 g USG application at 7 DAT and Variety BR11 showed the maximum tillers at 45 DAT (24.67), 60 DAT (22.33) and 75 DAT (17.0). Interaction of $N_2 \times V_4$ also produced maximum number of tillers at 75 DAT (17.0). Interaction of urea fertilizer application as 1/3 at 15 DAT+ 1/3 30 DAT+ 1/3 at 50 DAT and BRRI dhan46 produced the minimum number of tillers throughout the growth period.

Table 2. Combined effect of urea fertilizer application method and variety on tillering pattern

Treatments	Tiller hill^{-1}				
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
$N_1 \times V_1$	8.67 a	15.00 a	22.33 ab	20.33 ab	16.67 ab
$N_1 \times V_2$	4.67 b	8.33 bc	12.00 de	11.33 de	9.33 de
$N_1 \times V_3$	6.33 ab	14.67 a	18.00 a-d	17.33 abcd	15.33 a-c
$N_1 \times V_4$	5.00b	11.00 a-c	22.67 ab	20.67 a	13.00 a-e
$N_2 \times V_1$	5.00 b	10.67 a-c	22.00 ab	20.33 ab	15.33 a-c
$N_2 \times V_2$	6.00ab	9.00 bc	14.67 c-e	14.33 bcde	10.67 c-e
$N_2 \times V_3$	4.33b	10.33 a-c	17.33 b-e	16.33 abcd	14.00 a-d
$N_2 \times V_4$	3.67b	8.67 bc	21.33 ab	19.67 ab	17.00 a
$N_3 \times V_1$	8.67a	11.00 a-c	24.67 a	22.33 a	17.00 a
$N_3 \times V_2$	4.67b	7.33 c	17.67 b-d	17.33 abcd	11.00 b-e
$N_3 \times V_3$	6.00ab	10.33 a-c	20.00 a-c	19.00 abc	13.67 a-e
$N_3 \times V_4$	5.33b	13.00 ab	21.67 ab	20.67 a	15.67 a-c
$N_4 \times V_1$	4.00b	8.00 bc	13.67 c-e	13.67 cde	12.33 a-e
$N_4 \times V_2$	3.67b	6.33 c	10.67 e	9.67 e	8.00 e
$N_4 \times V_3$	6.00ab	8.00 bc	14.00 c-e	13.00 de	12.00 a-e
$N_4 \times V_4$	4.67b	7.17 c	12.33 de	12.00 de	10.00 c-e
CV (%)	27.09	25.99	19.63	18.66	22.92
LSD $_{(0.05)}$	2.473	4.348	5.893	5.268	5.094

V_1 = BR11 V_2 = BRRI dhan33 V_3= BRRI dhan39 V_4 = BRRI dhan46

N_1 = 15 kgN ha^{-1} as prilled urea at final land preparation + 15 kg N ha^{-1} as prilled urea at 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT

N_2= 15 kg N ha^{-1} as prilled urea at 7 DAT + 15 kg N ha^{-1} as prilled urea at 30 DAT + 15 kg N ha^{-1} as prilled urea at 50 DAT

N_3= 60 kg ha^{-1} USG at 7 DAT

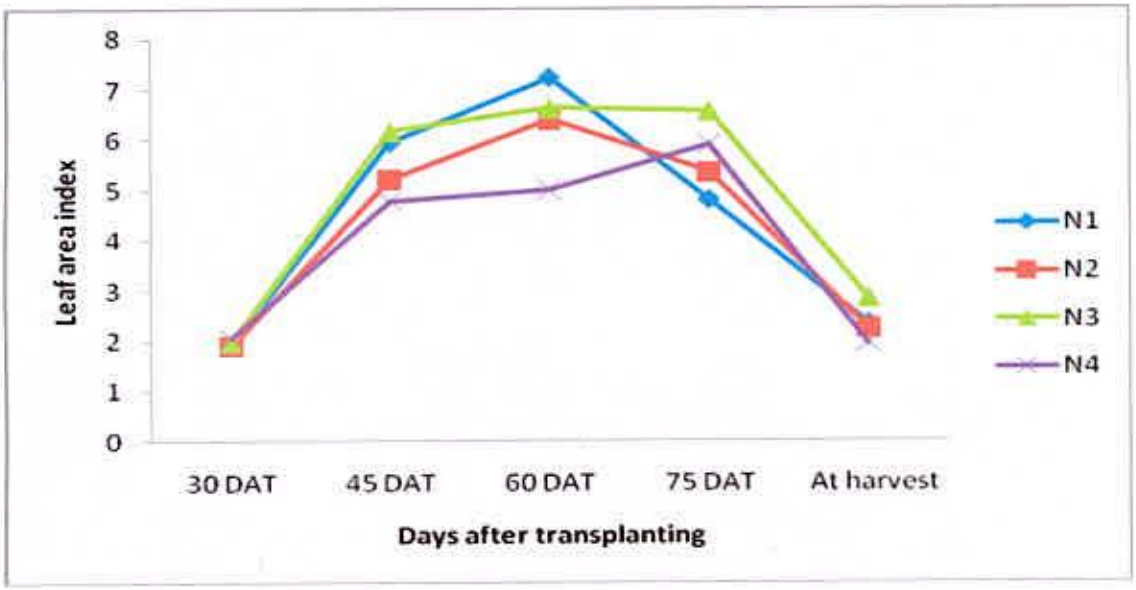
N_4= 15 kg N ha^{-1} as prilled urea at 15 DAT+ 15 kg N ha^{-1} as prilled urea 30 DAT+ 15 kgN ha^{-1} as prilled urea at 50 DAT

4.1.3 Effect on leaf area index

4.1.3.1 Effect of urea fertilizer application method

Variations in leaf area index for urea fertilizer application methods were statistically different at 45, 60, 75 DAT and at harvest but insignificant at 30 DAT (Figure 5). The maximum leaf area index at 45 DAT (6.16), 75 DAT (6.55) and at harvest (2.83) were recorded for application of 1.8 g USG at 7 DAT. The minimum leaf area indexes at 45 DAT (4.78), 60 DAT (4.98) and at harvest (1.93) were recorded for application of recommended amount of urea

as 1/3 at 15 DAT+ 1/3 at 30 DAT+ 1/3 at 50 DAT. Similar result also found by Masum *et al.* (2008) who reported that leaf area index significantly higher in USG receiving plant than prilled urea.

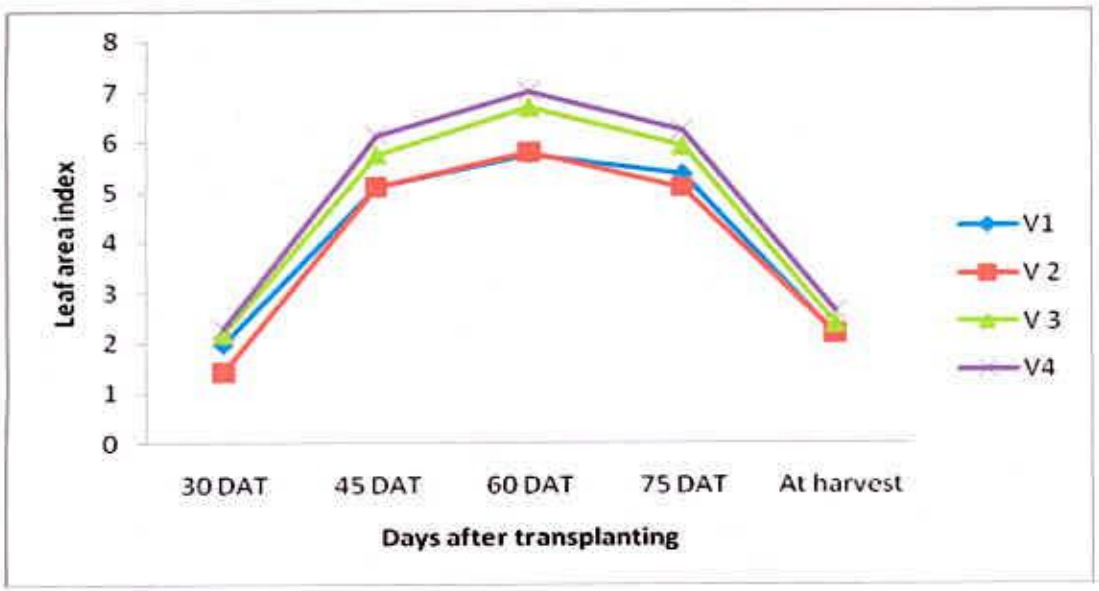


N_1 = 15 kg N ha^{-1} as prilled urea at final land preparation + 15 kgN ha^{-1} as prilled urea at 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT
N_2= 15 kg N ha^{-1} as prilled urea at 7 DAT + 15 kg N ha^{-1} as prilled urea at 30 DAT + 15 kg N ha^{-1} as prilled urea at 50 DAT
N_3 = 60 kg ha^{-1} USG at 7 DAT
N_4= 15 kg N ha^{-1} as prilled urea at 15 DAT+ 15 kg N ha^{-1} as prilled urea 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT

Figure 5. Effect of urea fertilizer application method on leaf area index of *aman* rice. [$LSD_{(0.05)}$ = 0.314, 0.4833, 0.557, 0.447, 0.243]

4.1.3.2 Effect of variety

Significant variations were observed on leaf area index in all cases for variety (Figure 6). The highest leaf area index at 30 DAT (2.27), 45 DAT (6.13), 60 DAT (6.99), 75 DAT (6.22) and at harvest (2.62) were recorded from BRRI dhan46 where BRRI dhan39 showed statistically similar result from 30 DAT to until harvest. At 30 DAT (1.42), 45 DAT (5.09) and 75 DAT (2.18) BRRI dhan33 showed the lowest leaf area index.



V_1 = BR11 V_2 = BRRI dhan33 V_3= BRRIdhan39 V_4 = BRRI dhan46

Figure 6. Effect of variety on Leaf area index of aman rice [LSD $_{(0.05)}$ = 0.314, 0.483, 0.557, 0.447, 0.243]

4.1.3.3 Combined effect of urea fertilizer application method and variety

There were significant variations observed on leaf area index for interaction effect of urea fertilizer application method and variety on leaf area index of aman rice from 30 DAT to until harvest (Table 3). Combination of 1.8 g USG application at 7 DAT and BRRI dhan46 showed the maximum leaf area index at 30 DAT (2.47), 45 DAT (6.73), 75 DAT (7.0) and harvest (3.2). At 60 DAT interaction of $N_1 \times V_4$ showed the highest leaf area index (7.90) and $N_3 \times V_4$ also showed statistically similar leaf area index (7.00). Interaction of urea fertilizer application as 1/3 at 15 DAT+ 1/3 30 DAT+ 1/3 at 50 DAT and variety BRRI dhan33 showed lowest leaf area index at 30 DAT (1.27), 45 DAT (4.10), 60 DAT (4.23) and at harvest (1.54).

Table 3. Combined effect of urea fertilizer application method and variety on leaf area index of aman rice

Treatments	Leaf area index				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
$N_1 \times V_1$	2.07 a-c	5.63 a-d	6.27 b-e	4.50 g	2.20 c-f
$N_1 \times V_2$	1.37 cd	5.80 a-d	6.97 ab	4.60 fg	2.27b-f
$N_1 \times V_3$	2.00 a-c	6.03 a-c	7.77 a	4.90 e-g	2.40 b-f
$N_1 \times V_4$	2.27 a	6.30 ab	7.90 a	5.20 d-g	2.47 b-e
$N_2 \times V_1$	1.90 a-d	4.73 de	5.50 d-f	4.70 fg	1.90 fg
$N_2 \times V_2$	1.27 d	4.27 e	6.23 b-e	4.57 g	2.10 c-f
$N_2 \times V_3$	2.27 a	5.87 a-c	6.73 a-d	5.84 b-e	2.30 b-f
$N_2 \times V_4$	2.13 ab	5.97 a-c	7.10 ab	6.27 a-c	2.63 bc
$N_3 \times V_1$	1.50 b-d	5.60 b-d	6.47 b-e	6.63 ab	2.53 b-d
$N_3 \times V_2$	1.77 a-d	6.20 ab	5.70 c-f	5.97 b-d	2.80 ab
$N_3 \times V_3$	2.10 ab	6.10 a-c	6.90 a-c	6.60 a-c	2.77 ab
$N_3 \times V_4$	2.47a	6.73 a	7.40 ab	7.00 a	3.20 a
$N_4 \times V_1$	2.40a	4.47 e	4.77 fg	5.60 c-f	1.97e-g
$N_4 \times V_2$	1.27d	4.10 e	4.23 g	5.20 d-g	1.54 g
$N_4 \times V_3$	2.30 a	5.00 c-e	5.37 e-g	6.33 a-c	2.03d-g
$N_4 \times V_4$	2.20 ab	5.53 b-d	5.57 d-f	6.40 a-c	2.17 c-f
CV (%)	18.98	10.39	10.49	9.41	12.36
$LSD_{(0.05)}$	0.628	0.967	1.114	0.895	0.243

V_1 = BR11 V_2 = BRRI dhan33 V_3= BRRI dhan39 V_4 = BRRI dhan46

N_1 = 15 kgN ha^{-1} as prilled urea at final land preparation + 15 kg N ha^{-1} as prilled urea at 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT

N_2= 15 kg N ha^{-1} as prilled urea at 7 DAT + 15 kg N ha^{-1} as prilled urea at 30 DAT + 15 kg N ha^{-1} as prilled urea at 50 DAT

N_3= 60 kg ha^{-1} USG at 7 DAT

N_4= 15 kg N ha^{-1} as prilled urea at 15 DAT+ 15 kg N ha^{-1} as prilled urea 30 DAT+ 15 kgN ha^{-1} as prilled urea at 50 DAT

4.2 Yield contributing characters

4.2.1 Effective tillers $hill^{-1}$

4.2.1.1 Effect of urea fertilizer application method

Variations in effective tillers $hill^{-1}$ for different urea fertilizer application methods were statistically significant (Table 4). Application of 1.8 g USG at 7 DAT (N_3) produced the highest number of effective tillers $hill^{-1}$ (11.75) where N_1 and N_2 also showed statistically similar result. Application of recommended amount of prilled urea as 1/3 at 15 DAT+ 1/3 at 30 DAT+ 1/3 at 50 DAT (N_4) produced the lowest number of tiller $hill^{-1}$ (8.00). This result was also in

agreement with the findings of Masum *et al.* (2010) who reported that placement of N fertilizer in the form of USG @ 58 kg N ha^{-1} produced the highest number of effective tillers $hill^{-1}$.

4.2.1.2 Effect of variety

Varietal difference showed significant influence on productive tillers $hill^{-1}$ (Table 4). The highest productive tiller produced by variety BR11 (12.17) where BRRI dhan39 and BRRI dhan46 also showed statistically similar result. BRRI dhan33 showed the lowest effective tillers $hill^{-1}$ (7.83).

4.2.1.3 Combined effect of urea fertilizer application method and variety

Interaction of urea fertilizer application method and variety significantly influence effective tillers $hill^{-1}$ (Table 5). Combination of 1.8 g USG application (N_3) and variety BR11 (V_1) produced the highest number of productive tiller $hill^{-1}$(14.00). Combination of recommended amount of prilled urea application as 1/3 during final land preparation+ 1/3 at 30 DAT+ 1/3 at 50 DAT (N_1) with BR11 (V_1), BRRI dhan33 (V_2), BRRI dhan39 (V_3), BRRI dhan46 (V_4); recommended amount of prilled urea application as 1/3 at 7 DAT + 1/3 at 30 DAT + 1/3 at 50 DAT (N_2) with variety V_1, V_3 and N_3 with V_1, V_3, V_4 also produce statistically similar productive tiller. The lowest number of productive tillers (6.67) recorded from N_4 and V_4 combination.

4.2.2 Panicle length

4.2.2.1 Urea fertilizer application method

There were no significant variation observed on panicle for different fertilizer application method (Table 4) though application of 1.8 g USG at 7 DAT (N_3) produced the longest panicle (25.66 cm) and application of recommended amount prilled urea as 1/3 during final land preparation+ 1/3 at 30 DAT+ 1/3 at 50 DAT (N_1) produced the shortest panicle (24.35 cm). Similar result also observed by Hasanuzzaman *et al.* (2009) who noted that urea supergranules produced longest panicle (22.3 cm).

4.2.2.2 Effect of variety

Influence of varietal variation showed significant influence on panicle length. BR11 produced the longest panicle (25.70 cm) and BRRI dhan39 and BRRI dhan46 also showed statistically similar result. BRRI dhan33 produced the shortest panicle (23.79 cm). This result was in agreement with Idris and Matin (1990) who observed that panicle length differed among the six rice varieties.

4.2.2.3 Combined effect of urea fertilizer application method and variety

There were significant variation observed for combined effect of urea fertilizer application method and variety on panicle length (Table 4). The largest panicle (27.27 cm) produced for the combination of recommended amount prilled urea application as 1/3 at 15 DAT + 1/3 at 30 DAT+ 1/3 at 50 DAT and variety BR11. Interaction with recommended amount prilled urea application as 1/3 at 7DAT + 1/3 at 30 DAT+ 1/3 at 50 DAT and variety BRRI dhan33 showed the shortest panicle (22.33 cm).

4.2.3 Filled grains panicle^{-1}

4.2.3.1 Effect of urea fertilizer application method

Statistically significant variation observed on filled grains panicle^{-1} for different urea fertilizer application method (Table 4). Application of 1.8 g USG at 7 DAT (N_3) produced the highest number of filled grains panicle^{-1} (132.09). The lowest number of filled grain panicle^{-1} was recorded from N_1 (103.17) where N_2 and N_4 also showed statistically similar result. Ahmed *et al.* (2000) also found the same result who reported that USG was more efficient than PU at all respective levels of N in producing filled grains panicle^{-1}.

4.2.3.2 Effect of variety

Variations in filled grains panicle^{-1} for varietal differences were statistically significant (Table 4). The highest number of filled grains recorded from BRRI dhan39 (135.83) and the lowest from BRRI dhan33 (90.25). Similar result was found by Guilani *et al.* (2003) who reported variation grain fertility percentages were different among cultivars.

4.2.3.3 Combined effect of urea fertilizer application method and variety

Combination of urea fertilizer application method and variety significantly affect the number of filled gains panicle^{-1} (Table5). Combination of recommended amount of prilled urea application as 1/3 at 7DAT + 1/3 at 30 DAT+ 1/3 at 50 DAT and variety BRRI dhan39 produce the highest number of filled grains panicle (146.00). Interaction with N_2 and V_2; N_3 and V_1, V_2, V_3, V_4; N_4 and V_3 also showed statistically similar result. Interaction of N_1 and V_2 produce the lowest number of filled grains panicle^{-1} (58.0).

4.2. 4 Unfilled grains panicle^{-1}

4.2.4.1 Urea fertilizer application method

Statistically significant variation observed on unfilled grains for different urea fertilizer application method (Table 4). Application of recommended amount of prilled urea as as 1/3 at 15 + 1/3 at 30 + 1/3 at 50 DAT (N_4) produced the the highest number of unfilled grains panicle^{-1} (37.33) where application of 1.8 g USG at 7 DAT (N_3) produced lowest number of unfilled grains panicle^{-1} (27.75). Dissimilar result observed by Hasan *et al.* (2002) who stated the response of hybrid (Sonar Bangla-1 and Alok 6201) and inbred (BRRI dhan 34) rice varieties to the application methods of urea supergranules (USG) and prilled urea (PU) and reported that the effect of application method of USG and PU was not significant in respect of number of unfilled grains panicle^{-1} and 1000-grains weight.

4.2.4.2 Effect of variety

Significant variation observed on unfilled grains panicle^{-1} for varietal differences. The maximum unfilled grains panicle $^{-1}$ observed from BRRI dhan33 (43.33) and minimum from BRRI dhan39 (28.17) where BR11 and BRRI dhan46 showed statistically similar result.

Table 4. Effect of urea fertilizer application method, variety and their combination on yield contributing character of *aman* rice

Treatments	Effective tiller hill^{-1}	Panicle length (cm)	Filled grain panicle^{-1}	Unfilled grain panicle^{-1}	Total grain panicle^{-1}	1000 grain weight (g)
Effect of urea fertilizer application method						
N_1	11.42 a	24.35	103.17 b	39.92 ab	137.08 b	25.77 bc
N_2	10.50 a	24.65	104.17 b	34.58 ab	138.75 b	26.55ab
N_3	11.75 a	25.66	132.09 a	27.75 b	159.83 a	27.50a
N_4	8.00 b	25.33	104.50 b	37.33 a	141.83 b	25.26c
CV (%)	20	6.11	8.86	23.21	10.25	4.48
LSD $_{(0.05)}$	1.755	NS	8.289	6.532	12.47	0.992
Effect of variety						
V_1	12.17 a	25.70 a	111.25 b	32.25 b	143.50 b	26.74 b
V_2	7.83 b	23.79 b	90.25 c	43.33 a	133.58 b	24.19 c
V_3	10.58 a	25.18 a	135.83 a	28.17 b	164.00 a	25.97 b
V_4	11.08 a	25.31 a	106.58 b	29.83 b	136.42 b	28.17 a
CV (%)	20.00	6.11	8.86	23.21	10.25	4.48
LSD $_{(0.05)}$	1.755	1.286	8.289	6.532	12.47	0.992
Combined effect of urea fertilizer application method and variety						
$N_1 \times V_1$	13.67 a	24.47 a-c	114.67 bc	27.33 d-f	142.00 a-d	24.97 b-e
$N_1 \times V_2$	7.667 cd	23.77 bc	58.00 f	49.00 a	107.00 e	23.58 e
$N_1 \times V_3$	12.00 ab	25.00 a-c	146.00 a	20.00 f	166.00 a	25.79 b-e
$N_1 \times V_4$	12.33 ab	24.17 bc	94.00 de	39.33 a-d	133.33 b-e	28.75 a
$N_2 \times V_1$	12.33 ab	24.73 a-c	97.00 cd	37.67 a-d	134.67 b-e	25.11 b-e
$N_2 \times V_2$	7.67 cd	22.33 c	78.00 e	46.67 a-c	124.67 de	24.93 b-e
$N_2 \times V_3$	10.00 a-d	25.33 a-c	136.00 a	32.00 d-f	168.00 a	26.51 bc
$N_2 \times V_4$	12 ab	26.20 ab	105.67 cd	22.00 ef	127.67 de	29.63 a
$N_3 \times V_1$	14.00 a	26.33 ab	136.00 a	27.67 d-f	163.67 a	30.32 a
$N_3 \times V_2$	9.33 b-d	24.87 a-c	128.00 ab	30.00 d-f	158.00 ab	24.03 de
$N_3 \times V_3$	11.33 a-c	25.03 a-c	132.67 ab	28.67 d-f	161.33 ab	25.56 b-e
$N_3 \times V_4$	12.33 ab	26.40 ab	131.67 ab	24.67 d-f	156.33 a-c	30.07 a
$N_4 \times V_1$	8.67 b-d	27.27 a	97.33 cd	36.33 a-e	133.67 b-e	26.54 b
$N_4 \times V_2$	6.67 d	24.20 bc	97.00 cd	47.67 ab	144.67 a-d	24.23 b-e
$N_4 \times V_3$	9.00 b-d	25.37 ab	128.67 ab	32.00 c-f	160.67 ab	26.01 b-d
$N_4 \times V_4$	7.67 cd	24.47 a-c	95.00 de	33.33 b-f	128.33 c-e	24.24 c-e
CV (%)	20.00	6.11	8.86	4.475	10.25	4.48
LSD $_{(0.05)}$	3.511	2.573	16.58	1306	24.94	0.992

4.2.4.3 Combined effect of urea fertilizer application method and variety

Statistically significant varations was observed for interaction of urea fertilizer application method and variety on unfilled grans panicle^{-1} (Table 5). The highest unfilled grains panicle^{-1} (49.00) found from the interaction of recommended urea fertilizer application as1/3 during final land preparation + 1/3 at 30 DAT+ 1/3 at 50 DAT (N_1) and variety BRRI dhan33 (V_2). The lowest unfilled grains panicle^{-1} (20.00) found from the interaction of N_1 and BRRI dhan39 (V_3).

4.2.5 Total grains panicle^{-1}

4.2.5.1 Effect of urea fertilizer application method

Influence of urea fertilizer application method showed significant effect on total grains panicle^{-1}(Table 4). Application of 1.8 g USG at 7 DAT (N_3) produced the highest number of total grains panile^{-1} (159.83). Application of recommended amount of urea as 1/3 during final land preparation+ 1/3 at 30 DAT+ 1/3 at 50 DAT (N_1) produced the lowest total number of grains panicle^{-1} (137.08) where N_2 and N_4 also showed statistically similar result.

4.2.5.2 Effect of variety

Statistically significant variation observed for varietal variation on total grains panicle $^{-1}$ (Table 4). BRRI dhan39 produced the highest number of total grains panicle (164.0) and BRRI dhan33 produced the lowest number of total grains panicle^{-1} (133.58) where BR11 and BRRI dhan46 showed statistically similar result. This result was in agreement with Kamal *et al.* (1988) who stated that number of grain panicle^{-1} was differed among different varieties.

4.2.5.3 Combined effect of urea fertilizer application method and variety

There were significant variation found for the combination of urea fertilizer application method and variety on total number of grains panicle^{-1} (Table 5). The highest total number of grains panicle^{-1} (168.00)

recorded for the interaction of recommended amount urea fertilizer application as as1/3 at 7 DAT+ 1/3 at 30 DAT+ 1/3 at 50 DAT (N_2) and variety BRRI dhan39 (V_3). Combination of N_1 and V_2 produced the lowest total grain panicle^{-1} (107.00)

4.2.6 1000-grain weight

4.2.6.1 Effect of urea fertilizer application method

Variations in 1000-grain weight for different urea fertilizer application method were significant (Table 4). The highest 1000 grain weight (27.50 g) was recorded from the application of 1.8 g USG at 7 DAT (N_3) and the lowest 1000 grain weight (25.26 g) was recorded form N_4.

4.2.6.2 Effect of variety

There were significant variations observed for varietal variation on 1000-grain weight (Table 4). The highest 1000 grain weight recorded from BRRI dhan46 (28.17 g) and the lowest from BRRI dhan33 (24.19 g). BR11 and BRRI dhan39 showed statistically similar result. Similar result observed by Rafey *et al.* (1989) who reported that weight of 1000 grains differed among the different rice cultivars studied.

4.2.6.3 Combined effect of urea fertilizer application method and variety

Variations in 1000 grain weight for interaction of urea fertilizer application method and variety were statistically significant (Table 5). The highest 1000-grain weight (30.32 g) was produced from the interaction 1.8 g USG application at 7 DAT (N_3) and variety BR11(V_1). Combination with N_1 and V_4, N_2 and V_4, N_3 and V_4 also statistically showed the maximum 1000-grain weight. Combination of recommended prilled urea application as 1/3 during final land preparation + 1/3 at 30 DAT+ 1/3 at 50 DAT (N_1) and variety BRRI dhan33 (V_2) showed the lowest 1000 grain weight (23.58 g).

4.3 Yield

4.3.1 Grain yield

4.3.1.1 Urea fertilizer application method

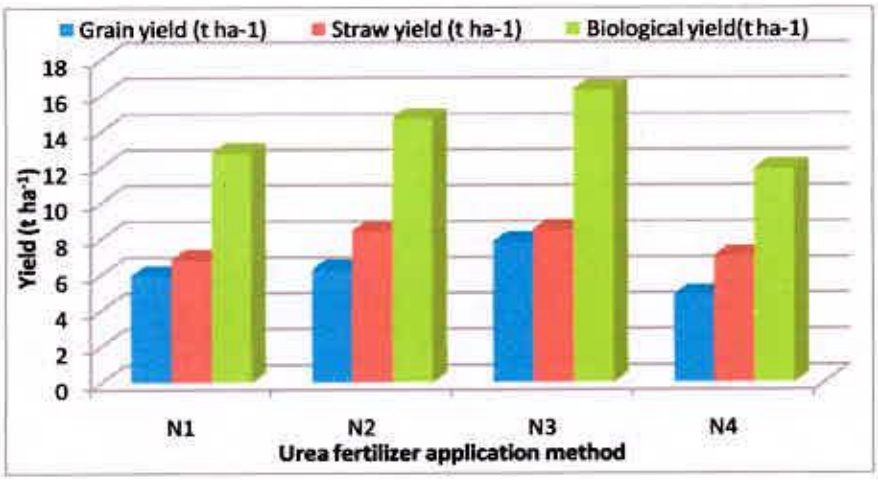
Statistically significant variations were observed on grain yield for different urea fertilizer application method (Figure 7). The highest grain yield (7.82 t ha^{-1}) was observed for the application of 1.8 g USG application at 7 DAT. The lowest (4.88 t ha^{-1}) grain yield was recorded from the application of recommended amount of prilled urea as 1/3 at 15 + 1/3 at 30 + 1/3 at 50 DAT (N_4). Statistically similar result was found by Kabir *et al.* (2009) who observed that the highest grain yield (5.17 t ha^{-1}), straw yield (6.13 t ha^{-1}) and harvest index (46.78%) were found from full dose of USG than PU. Ahmed *et al.* (2000) also revealed that USG was more efficient than PU at all respective levels of N in producing all yield components and in turn, grain and straw yields.

4.3.1.2 Effect of variety

Significant variations was observed on grain yield for varietal differences (Figure 8). The highest grain yield (8.17 t ha^{-1}) was recorded form BR11 (V1) and lowest grain yield (2.87 t ha^{-1}) for BRRI dhan33 (V_2). BRRI dhan46 showed statistically similar result with BR11. This result was in agreement with the finding of Patel (2000) who reported that yield performance varied with variety.

4.3.1.3 Combined effect of urea fertilizer application method and variety

Statistically significant variations were observed on grain yield for interaction of urea fertilizer application method and variety (Table 6). The highest grain yield (10.67 t ha^{-1}) was recorded for the interaction of 1.8 g USG application at 7 DAT and with variety BR11. Interaction of N_2 with V_1 and N_3 with V_4 also showed statistically similar result. The lowest grain yield (2.0 t ha^{-1}) was recorded from the interaction of N_4 with V_2 where interaction with $N_1 \times V_2$ and $N_2 \times V_2$ showed statistically similar result.



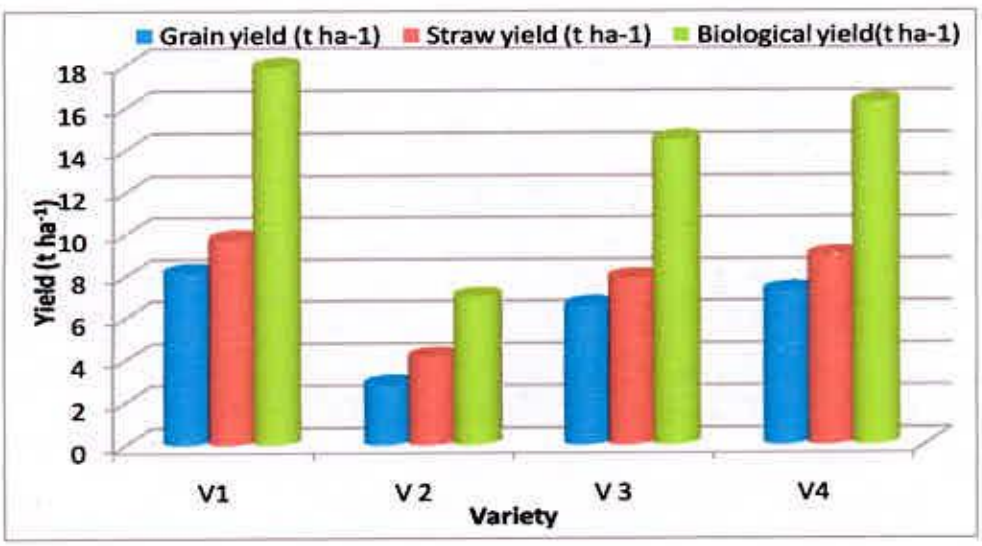
N_1 = 15 kg N ha^{-1} as prilled urea at final land preparation + 15 kg N ha^{-1} as prilled urea at 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT

N_2= 15 kg N ha^{-1} as prilled urea at 7 DAT + 15 kg N ha^{-1} as prilled urea at 30 DAT + 15 kg N ha^{-1} as prilled urea at 50 DAT

N_3= 60 kg ha^{-1} USG at 7 DAT

N_4= 15 kg N ha^{-1} as prilled urea at 15 DAT+ 15 kg N ha^{-1} as prilled urea 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT

Figure 7. Effect of urea fertilizer application method on grain yield, straw yield and biological yield of aman rice [LSD $_{(0.05)}$ = 1.346, 0.955, 1.684]



V_1 = BR11 V_2 = BRRI dhan33 V_3= BRRIdhan39 V_4 = BRRI dhan46

Figure 8. Effect of variety on grain yield, straw yield and biological yield of *aman* rice [LSD $_{(0.05)}$ = 1.346, 0.955, 1.684]

4.3.2 Straw yield

4.3.2.1 Urea fertilizer application method

There were significant variation on among observed for different urea fertilizer application methods on straw yield (Figure 7). The highest straw yield (8.50 t ha^{-1}) was recorded from application of 1.8 g USG application at 7 DAT (N_3) and this result was also statistically similar with N_2 method. The lowest straw yield (6.83 t ha^{-1}) recorded from the application of recommended amount of prilled urea as 1/3 during final land preparation + 1/3 at 30 + 1/3 at 50 DAT (N_1) and this result statistically similar with N_4.

4.3.2.2 Effect of variety

Variations in straw yield for varietal differences were statistically significant (Figure 8). Numerically the highest straw yield (9.75 t ha^{-1}) was found from the BR11 variety and BRRI dhan46 showed statistically similar result. The lowest straw yield (4.17 t ha^{-1}) was recorded from the variety BRRI dhan33. Similar result found by Mishra *et al.* (1999) who noticed the placement of USG significantly increased both the grain and straw yield of rice compared to PU.

4.3.2.3 Combined effect of urea fertilizer application method and variety

Interaction of urea fertilizer application method and variety significantly influenced the straw yield (Table 6). The highest straw yield (12.00 t ha^{-1}) was recorded for the interaction of 1.8 g USG application at 7 DAT with the variety BR11 where interaction of N_2 and V_1 showed statistically similar result. The lowest straw yield (3.0 t ha^{-1}) was recorded from the interaction of N_1 with V_2 where, interaction with $N_3 \times V_2$, $N_2 \times V_2$ and $N_4 \times V_2$ showed statistically similar results.

4.3.3 Biological yield

4.3.3.1 Effect of urea fertilizer application method

Variations in biological yield for different urea fertilizer application methods were statistically significant (Figure 7). The highest biological yield (16.32 t ha^{-1}) was recorded from application of 1.8 g USG application at 7 DAT (N_3) which was statistically similar with N_2. The lowest biological yield (11.32 ha^{-1}) was recorded from N_4 method, which was statistically similar with N_1.

4.3.3.2 Effect of variety

There were significant variations observed for varietal differences on biological yield (Figure 8). The highest biological yield (17.92 t ha^{-1}) was found from the variety BR11 (V_1) and the lowest (7.03 t ha^{-1}) from BRRI dhan33 (V_2). BRRI dhan46 showed statistically similar result with BR11.

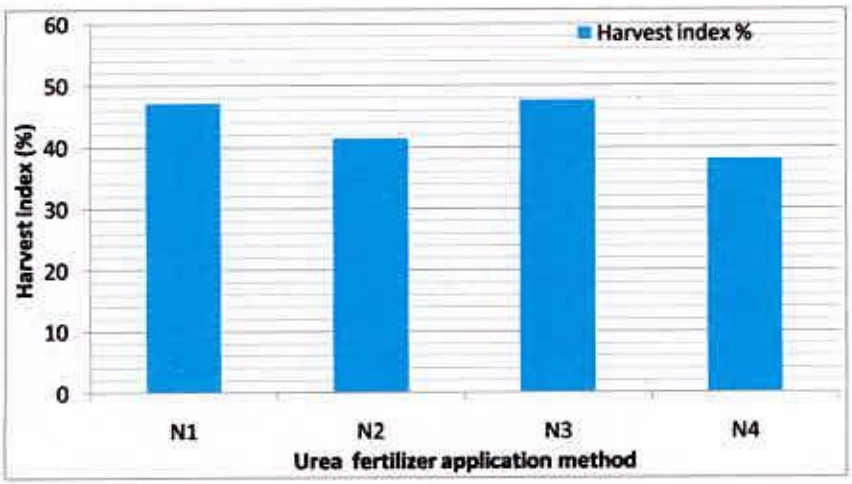
4.3.3.3 Combined effect of urea fertilizer application method and variety

Variations in biological yield for interaction of urea fertilizer application method and variety were statistically significant (Table 6). Interaction of 1.8 g USG application at 7 DAT and variety BR11 showed the maximum biological yield (22.67 t ha^{-1}). The lowest biological yield (5.93 t ha^{-1}) was observed from the interaction of recommended amount of prilled urea application as1/3 during final land preparation + 1/3 at 30 DAT+ 1/3 at 50 DAT (N_1) with the variety BRRI dhan33 (V_2) where interaction of $N_2 \times V_2$, $N_3 \times V_2$ and $N_4 \times V_2$ was also showed statistically similar result.

4.3.4 Harvest index

4.3.4.1 Effect of urea fertilizer application method

Significant variation was observed on harvest index (%) for different fertilizer application method (Figure 9). The highest harvest index found (47.67%) from the application of 1.8 g USG application at 7 DAT and numerically the lowest harvest index (38.08) was from the application of recommended amount of prilled urea as 1/3 during final land preparation + 1/3 at 30 DAT+ 1/3 at 50 DAT.



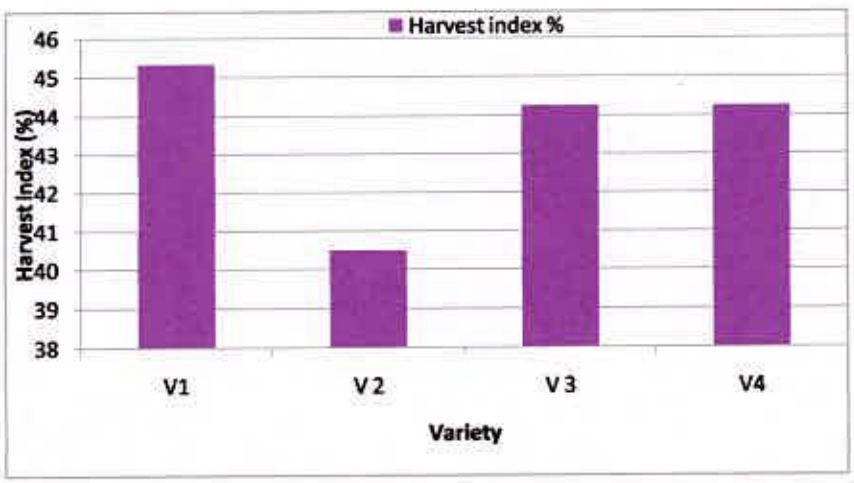
N_1 = 15 kg N ha^{-1} as prilled urea at final land preparation + 15 kg N ha^{-1} as prilled urea at 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT

N_2= 15 kg N ha^{-1} as prilled urea at 7 DAT + 15 kg N ha^{-1} as prilled urea at 30 DAT + 15 kg N ha^{-1} as prilled urea at 50 DAT

N_3= 60 kg ha^{-1} USG at 7 DAT

N_4= 15 kg N ha^{-1} as prilled urea at 15 DAT+ 15 kg N ha^{-1} as prilled urea 30 DAT+ 15 kg N ha^{-1} as prilled urea at 50 DAT

Figure 9. Effect of urea fertilizer application method on harvest index (%) of *aman rice* [$LSD_{(0.05)} = 0.080$]



V_1 = BR11 V_2 = BRRI dhan33 V_3= BRRIdhan39 V_4 = BRRI dhan46

Figure 10. Effect of variety on harvest index of *aman* rice [$LSD_{(0.05)} = 0.080$]

4.3.4.2 Effect of variety

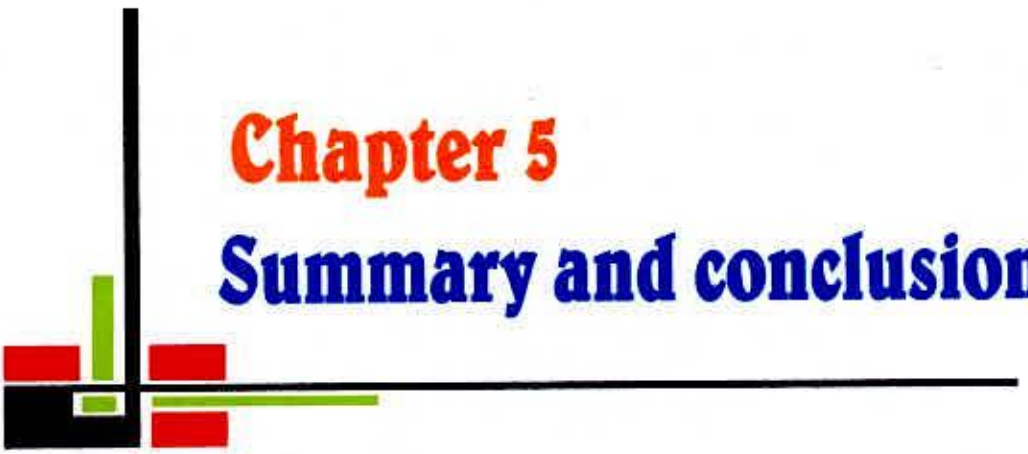
There were observed significant variations on harvest index (%) for varietal variation (Figure 10). Numerically the highest harvest index (45.33%) was recorded from the variety BR11 and lowest harvest index (40.50%) recorded from the variety BRRI dhan33.

4.3.4.3 Combined effect of urea fertilizer application method and variety

There were no significant variation observed on harvest index for interaction of urea fertilizer application method and variety (Table 6). The interaction of recommended amount of prilled urea application as1/3 during final land preparation + 1/3 at 30 DAT+ 1/3 at 50 DAT (N_1) with the variety BRRI dhan33 showed the highest harvest index (49.67%) . The interaction of recommended amount of prilled urea application as1/3 at 15 DAT+ 1/3 at 30 DAT+ 1/3 at 50 DAT (N_1) and variety BRRI dhan33 (V_2) showed the lowest harvest index (32.00%).

Table 6. Combined effect of urea fertilizer application method and variety on grain yield, straw yield, biological yield and harvest index of aman rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index %
$N_1 \times V_1$	7.33 bcd	8.00 cd	15.33 b-d	48.00
$N_1 \times V_2$	2.93fg	3.00 e	5.93 e	49.67
$N_1 \times V_3$	6.50 b-e	7.83 cd	14.33 cd	45.67
$N_1 \times V_4$	7.03 b-d	8.50 b-d	15.53 b-d	45.33
$N_2 \times V_1$	8.50 a-c	10.33 ab	18.83 b	45.00
$N_2 \times V_2$	2.60 fg	4.83 e	7.43 e	35.00
$N_2 \times V_3$	7.27 b-d	9.17 b-d	16.43 bc	44.00
$N_2 \times V_4$	6.83 b-e	9.33 bc	16.17 b-d	41.67
$N_3 \times V_1$	10.67 a	12.00 a	22.67 a	47.33
$N_3 \times V_2$	3.93 e-g	4.67 e	8.60 e	45.33
$N_3 \times V_3$	7.33 b-d	7.67 cd	15.00 cd	48.67
$N_3 \times V_4$	9.33 ab	9.67 bc	19.00 b	49.33
$N_4 \times V_1$	6.17 c-e	8.67 b-d	14.83 cd	41.00
$N_4 \times V_2$	2.0 g	4.17 e	6.17 e	32.00
$N_4 \times V_3$	5.33 d-f	7.00 d	12.33 d	38.67
$N_4 \times V_4$	6.00 c-e	8.33 b-d	14.33 cd	40.67
CV%	25.63	14.72	1.154	21.77
$LSD_{0.05}$	2.693	1.910	3.369	0.080



Chapter 5

Summary and conclusion

SUMMARY AND CONCLUSION

A field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University (SAU), during July through December, 2010 with view to finding out the modern varietal performance of *aman* rice as affected by different methods of urea application. The experimental treatments included four variety i.e. BR11, BRRI dhan33, BRRIdhan39, BRRI dhan46 and four urea application methods viz. 15 kg ha^{-1} N as prilled urea at final land preparation + 15 kg ha^{-1} N as prilled urea at 30 DAT+ 15 kg ha^{-1} N as prilled urea 50 DAT; 15 kgha^{-1} N as prilled urea at 7 DAT + 15 kg ha^{-1}N as prilled urea at 30 DAT + 15 kg ha^{-1} N as prilled urea at 50 DAT; 60 kg ha^{-1} USG (1.8 g) at 7 DAT; 15 kg ha^{-1} N as prilled urea at 15 DAT+ 15 kg ha^{-1} N as prilled urea 30 DAT+ 15 kg ha^{-1} N as prilled urea at 50 DAT. The experiment was laid out in a split plot design with three replications having urea application in the main plots and variety in the sub-plots. There were 16 treatment combinations. The total number of unit plots were 48. The size of unit plot was 3 m × 2.5 m (7.5 m^2). Seedlings were transplanted with 25 cm spacing between lines and 15 cm spacing between hills. Intercultural operations such as gap filling, weeding, water management and pest management were done as and when necessary. Maturity of crop was determined when 90% of the grains become golden yellow in color.

The data on crop growth characters like plant height, number of tillers $hill^{-1}$ were recorded at 15, 30, 45, 60 and 75 DAT and leaf area index were recorded at 15, 30, 45, 60, 75 DAT and at harvest in the field and yield as well as yield contributing characters like number of effective tillers $hill^{-1}$, panicle length, number of grains $panicle^{-1}$, percent filled and unfilled grains, 1000-grain weight, grain and straw yield were recorded after harvest. Finally grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1} and analyses using the analysis of variance techniques using MSTAT-C package.

The findings showed that urea fertilizer application method significantly influenced plant height, tillering pattern, leaf area index, effective tillers hill^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, total grains panicle^{-1}, weight of 1000-grain weight, grain yield, straw yield, biological yield and harvest index. The highest plant height at 15 DAT (48.77 cm), 30 DAT (65.44cm), 45 DAT (86.25 cm) and maximum tillers hill^{-1} at 45 DAT (21.00), 60 DAT (19.83), 75 DAT (14.33) were found for application of 1.8 g USG at 7 DAT. The maximum leaf area index at 45 DAT (6.158), 75 DAT (6.55) and at harvest (2.85) were also recorded for the application of 1.8 g USG at 7 DAT. The highest effective tillers hill^{-1} (11.75), filled grains panicle (132.09), weight of 1000 grain (27.05 g), grain yield (7.82 t ha^{-1}), straw yield (8.50 t ha^{-1}), biological yield (16.32 t ha^{-1}), harvest index (47.67%) were also recorded for the application 1.8 g USG @ 60 kg ha^{-1} at 7 DAT. Application of prilled urea as 1/3 at 7 DAT, 1/3 at 30 DAT. 1/3 at 50 DAT @ N 45 kg ha^{-1} also showed statistically similar straw yield (8.42 t ha^{-1}) and biological yield (12 t ha^{-1}).

Influence of variety were significant on tillering pattern, leaf area index, effective tillers hill^{-1}, filled grain panicle^{-1}, weight of 1000 grain, grain yield, straw yield and biological yield. The highest tillers hill^{-1} at15 DAT (6.58). 30 DAT (11.17), 45 DAT (20.67), 60 DAT (19.17) and 75 DAT (15.33) were recorded from BR11 variety but the maximum leaf area index (6.133 at 45 DAT and 6.992 at 60 DAT) all over the growth period were recorded from BRRI dhan46. The highest effective tillers hill^{-1} (12.17) from BR11, filled grains panicle^{-1} (135.83) from BRRI dhan39, weight of 1000 grain (28.17 g) from BRRI dhan46 was recorded. The highest grain yield (8.17 t ha^{-1}), straw yield (9.75 t ha^{-1}) and biological yield (17.92 t ha^{-1}) were recorded from BR11 variety. BRRI dhan46 also showed statistically similar grain yield (7.30 t ha^{-1}), straw yield (8.96 t ha^{-1}) and biological yield (16.26 t ha^{-1}).

Combined effect of urea fertilizer application method and variety showed significant effect on plant height, tillering pattern, leaf area index, effective tillers hill^{-1}, filled grains panicle^{-1}, 1000 grain weight, grain yield and straw yield. Combination of 1.8 g USG application and BR11 variety showed the highest effective tillers hill^{-1} (14.00), 1000 grain weight (30.32 g), grain yield (10.67 t ha^{-1}), straw yield (12.00 t ha^{-1}) and biological yield (22.67 t ha^{-1}). Interaction of recommended prilled urea application as 1/3 at 7 DAT, 1/3 at 30 DAT, 1/3 at 50 DAT and variety BRRI dhan39 showed statistically similar grain yield (8.50 t ha^{-1}) and straw yield (10.33 t ha^{-1}).

Plant height, tillering pattern, leaf area index, effective tillers hill^{-1}, filled grains panicle^{-1}, weight of thousand grain, grain yield, straw yield and harvest index revealed higher by application of 1.8 g USG at 7 DAT, variety BR11 and their interaction. In some cases application of prilled urea as 1/3 at 7 DAT+ 1/3 at 30 DAT+ 1/3 at 50 DAT @ 45 kg N ha^{-1}, variety BRRI dhan39 and their interaction also showed statistically similar result.

However to reach a specific recommendation, more research work on wider range of urea fertilizer application method and variety on performance of *aman* rice should be done over different Agro-ecological zones.

References

REFERENCES

Ahmed, M. H., Islam, M. A., Kader, M. A. and Anwar, M. P. (2000). Evaluation of urea supergranules as a source of nitrogen in T. *aman* rice. *Pakistan J. Biol. Sci.* **2**(5): 735-737.

Ahmed, M. R., Rashid, M. A., Alam, M. S., Billah, K. A. and Jameel, F. (1997). Performance of eight transplant aman rice varieties under irrigated Conditions. *Bangladesh Rice J.* **8**(1 &2): 43-44.

Alam, B. M. R. (2002). Effect of different level of urea super granule on the growth and yield of three varieties of *boro* rice. MS (Ag.) Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh. p.119.

Ali, M. G., Mannan, M. A., Halder, K. P. and Siddique, S. B (1993). Effect of planting dates on the growth and yield of modern transplanted *aman* rice. Annals-of-Bangladesh-Agriculture. **3**(2): 103-108.

Ali, M. I. (1985). Nitrogen fertilizer efficiency in two major rice soils of Bangladesh. *Intl. Rice Res. Newsl.* **10**(6): 23-24.

Amin, M. R., Hamid, A., Choudhury, R. U., Raquibullah, S. M. and Asaduzzaman M. (2006). Nitrogen fertilizer effect on tillering, dry matter production and yield of traditional varieties of rice. *Int. J. Sustain. Crop Prod.* **1**(1): 17-20.

Balaswamy, K. (1999). Influence of different pre-emergence herbicides in relation to forms of urea on weed control and crop performance in transplanted rice. *J. Res. ANGRAU.* **27**(4): 1-6.

Bastia, D. K. and Sarker, R. K. (1995). Response of wetland rice to modified forms of urea. *Current Agril. Res.* **8**: 29-31.

BBS (Bangladesh Bureau of Statistics). (1998). Household Expenditure Survey, 1995-96. Bangladesh Bureau of Statistics. Min. Plan. Govt. People's Repub. Bangladesh. pp. 593-619.

BBS (Bangladesh Bureau of Statistics). (2004). Monthly Statistical Bulletin. Statistics Division, Bangladesh Bureau of Statistics. Min. Plan. Govt. People's Repub. Bangladesh., Dhaka.

BBS (Bangladesh Bureau of Statistics). (2005). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Bangladesh Rice Knowledge Bank (BRKB). Available at the following web site: http://www.knowledgebank-brri.org.

BBS (Bangladesh Bureau of Statistics). (2009). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Min. Plan. Govt. People's Repub. Bangladesh. p. 450.

Bhagat, R. K., Srivastava, V. C. and Dhar, V. (1992). Relative efficiency of slow release N fertilizers and modified urea materials for rice in farmer's field. *J. Res. Birsa Agril. Univ.* **4**(1): 51-52.

Bhale, V. M. and Salunke, V. D. (1993). Response of upland irrigated rice to nitrogen applied through urea and supergranules. *Mysore J. Agric. Sci.* **27**(1): 1-4.

Bhardwaj, A. K. and Singh, Y. (1993). Increasing nitrogen use efficiency through modified urea materials in flood rice in mollisols. *Ann. Agril. Res.* **14**(4): 448-451.

Bhowmick, N. and Nayak, R. L. (2000). Response of hybrid rice (Oryza sativa) varieties to nitrogen, phosphorus and potassium fertilizers during dry (boro) season in West Bengal. *Indian J. Agron.* **45** (2): 323-326.

Bhuiyan, N. I., Miah, M. A. M. and Ishaque, M. (1998). Research on USG: Findings and Future Research Areas and Recommendation. Proc. National Workshop on Urea supergranules Technology, held at BARC, Dhaka, Bangladesh, 25 June, 1998.

BINA (Bangladesh Institute of Nuclear Agriculture). (1993). Annual Report (1992-93). Bangladesh Inst. Nucl. Agric. P. O. Box No. 4. Mymensingh. pp. 143-147.

Bisne, R., Motiramani, N. K. and Sarawgi, A. K. (2006). Identification of high yielding hybrids in rice. *Bangladesh J. Agril. Res.* **31**(1): 171-174.

BRRI (Bangladesh Rice Research Institue). (1995). Adhunik Dhaner Chash (in bengali). Pub no.5. Bangladesh Rice Res. Inst., Joydebpur, Gazipur. pp. 12, 20-21, 23.

BRRI (Bangladesh Rice Research Institute). (1985). Annual report for 1982. Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh. BRRI pub. No. 79. pp. 236-238.

BRRI (Bangladesh Rice Research Institute). (1991). Annual Report for 1988. Bangladesh Rice Res. Inst., Joydebpur, Gazipur. pp. 8-15.

BRRI (Bangladesh Rice Research Institute). (1994). Annual Report for 1993. Bangladesh Rice Res. Inst., Jodebpur, Gazipur. pp. 8-9.

BRRI (Bangladesh Rice Research Institute). (1997a). Bangladesh Rice Research Institute serving the nation. Bangladesh Rice Research Institute. Gazipur 1701, Bangladesh. p. 14.

BRRI (Bangladesh Rice Research Institute). (1997b). Adhunik Dhaner Chash (in bengali). Bangladesh Rice Res. Inst., Joydebpur, Gazipur. pp. 15-18.

BRRI (Bangladesh Rice Research Institute). (2006). Available at the following web site: http://www.knowledgebank-brri.org.

BRRI (Bangladesh Rice Research Institute). (2008 a). BRRI Annual Internal Review 2006-2007. Soil Science Devision. Bangladesh Rice Research Institute, Gazipur-1701.

BRRI (Bangladesh Rice Research Institute). (2008 b). Annual Report for 2007-2008. Bangladesh Rice Research Institute, Gazipur-1701.

BRRI (Bangladesh Rice Research Institute). (2009). BRRI Annual Internal Review 2007-2008. Soil Science Division. Bangladesh Rice Research Institute, Gazipur-1701.

Chakraborti, S. P., Chalam, A. B. and Mohanta, S. K. (1989). Comparative efficiency of prilled urea and urea supergranules for wetland rice. *Indian Soc. Sci.* **37**(1): 177-179.

Chandra, B. V., Mahedvappa, M., Krishnamurthy, A. H. and Bhaskar, V. (1992). Performance of IRRI rice hybrids in Mandya, Karnataka, India. *Intl. Rice Res. Newsl.* **17** (2): 6.

Chauhan, H. S. and Mishra, B. (1989). Fertilizer use efficiency of amended urea materials in flooded rice. *J. Agric. Sci.* **112**(2): 277-281.

Chodury, A. T. M. A. and Bhuiyan, N. I. (1991). Yield and nitrogen nutrition of modern rice as affected by nitrogen fertilization under irrigated culture. *Bangladesh Rice J.* **2**(1&2): 122-127.

Chowdhury, M. T. U., Sarker, A. U., Sarker, M. A. R. and Kashem, M. A. (1993). Effect of variety and number of seedlings $hill^{-1}$ on the yield and its components on late transplanted *aman* rice. *Bangladesh J. Agril. Sci.* **20**(2): 311-316.

Chowdhury, S. A., Majid, M. A., Huque, K. S., Islam, M. and Rahman, M. M. (1995). Effect of variety on yield and nutritive value of rice straw. *Asian-Australasian J. Ani. Sci.* **8**(4): 329-335.

Costa, D. J. and Hoque, M. N. (1986). Superimposed variety trial on T. *aman* [Transplanted rice in Bangladesh]. Proc. Central Review Workshop, On-Farm Research Div. Jul. 5-10. BARI., Joydebpur, Bangladesh. pp. 25-26.

Craswell, E. T. and Datta, S. K.D (1980). Recent developments in research on nitrogen fertilizers for rice. *Indian J. Agron.* **31**(4): 387-389.

Das, D. K. (1989). Efficiency of different urea materials for rainy season rice (*Oryza sativa*). *Indian J. Agril. Sci.* **59**(8): 534-536.

Das, S. and Singh, T. A. (1994). Nitrogen use efficiency by rice flood water parameters as affected by fertilizer placement techniques. *J. Indian Soc. Soil Sci.* **42**(1): 46-50.

Devaraju, K. M., Gowda, H. and Raju, B. M. (1998). Nitrogen response of Karnataka Rice Hybrid 2. *Int.Rice Res. Notes*. **23**(2): 43.

Dongarwar, U. R., Patankar, M. N and Pawar, W. S. (2003). Response of hybrid rice to different fertility levels. *J. Soils and Crops.* **13** (1): 120-122.

Dweivedi, R. K. and Bajpai, R. P. (1995). Effect of different sources of urea and nitrogen levels on low land rice. *J. Res. Birsa Agril. Univ.* **7**(2): 161-162.

Edwin, L. and Krishnarajan, J. (2005). Influence of irrigation and nitrogen management practices on yield of hybrid rice. *Agric. Sci. Digest.* **25**(4): 309-310.

Guilani, A. A., Siadat, S. A. and Fathi, G. (2003). Effect of plant density and seedling age on yield and yield components in 3 rice cultivars in Khusestan growth conditions. *Iranian J. Agric. Sci.* **34**(2): 427-438.

Harun, M. E., Quayum, M. A., Alam, M. S., Jabbar, M. A. and Quaum, A. (1993). Economic analysis of urea supergranules application in irrigated rice. *Bangladesh Rice J.* **4**(1&2): 23-27.

Harun, M. E., Rashid, A., Azmal, A. K. M., Mazid, M. A. and Jabber, M. A. (1995). A comparative study of super granular and prilled urea application in irrigated rice. *Bangladesh Rice J.* **6**(1&2): 13-16.

Hasan, M. S., Hossain, S. M. A., Salim, M., Anwar, M. P. and Azad, A. K. M. (2002). Response of Hybrid and Inbred rice Varieties to the Application Methods of Urea supergranules and Prilled Urea. *Pakistan J. Bio. Sci.* **5** (7): 746-748.

Hasanuzzaman, M. Nahar, K. Alam, M.M., Hossain, M. Z. and Islam, M. R. (2009). Response of transplanted rice to different application methods of urea fertilizer. *Intl. J. Sustain. Agric.* **1**(1):1-5.

Hossain, S. M. A and Alam, A. B. M. N. (1991). Productivity of cropping pattern of participating farmers. **In:** Fact searching and Intervention in two FSRDP Sites, Activities. 1980-1990. Farming system Research and Development Programme, BAU, Mymensingh, Bangladesh. pp. 41-44.

Idris, M. and Matin, M. A. (1990). Response of four exotic strains of *aman* rice to urea. *Bangladesh J. Agric. Assoc. China*. **118**: 48-61.

Islam, M. M. and Black, R. P. (1998). Urea supergranules technology impact and action plan for 1988-89. Proc. National Workshop on Urea supergranules (USG) Technology, held at BARC, Dhaka, Bangladesh, 25 June, 1998.

Islam,M.S. (1995). Effect of variety and fertilization on yield and nutrient uptake in transplant *aman* rice. M.S. thesis. Dept. Agron. Bangladesh Agril. Univ. Mymensingh. pp. 26, 29.

Jaiswal, V. P. and Singh, G. R. (2001). Performance of urea supergranules and prilled urea under different planting method in irrigated rice (*Oryza sativa). Indian J. Agric. Sci.* **71**(3): 187-189.

Jee, R. C. and Mahapatra, A. K. (1989). Effect of time of planting of some slow release nitrogen fertilizers on low land rice. *Int. Rice Res. Newsl.* **12**(4): 52-53.

Johnkutty, I. and Mathew, P. B. (1992). Large granule urea, an efficient and economic source of N for wetland rice. *Intl.Rice Res.Newsl.***17**(3):16-17.

Julfiquar, A. W., Haque, M. M., Haque, A. K. G. M. E. and Rashid, M. A. (1998). Current status of Hybrid Rice Research and Future Program in Bangladesh. Proc. Workshop on Use and Development of Hybrid Rice in Bangladesh, held at BARC, 18-19, May, 1998.

Kabir, M. H., Sarkar, M. A. R., and Chowdhury, A. K. M. S. H. (2009). Effect of urea super granules, prilled urea and poultry manure on the yield of transplant aman rice varieties. *J. Bangladesh Agril. Univ.* 7(2): 259-263.

Kumar, V. J. F., Balasubramanian, M. and Jesudas, D. M. (1996). Application of different forms of urea for rice. *J. Indian Soc. Soil Sci.* **44**(2): 267-270.

Lal, P., Gautam, R. C., Bisht, P. S. and Pandey, P. C. (1988). Agronomic and economic evaluation of urea supergranules and sulphur coated urea in transplanted rice. *Indian. J. Agron.* **33**(2): 186-190.

Mae, T. (1997). Physiological nitrogen efficiency in rice: nitrogen utilization, photosynthesis and yield potential. **In**: Plant Nutrition for Sustainable Food Production and Environment. T. Ando, K. Fujita, T. Mae, H. Matsumoto, S. Mori and J. Skiya, (Ed.). Kluwer Academic Publishers, Doordrecht, Netherlands. pp. 51-60.

Maitti, S., Naleshwar, N. and Pal, S. (2003). Response of high yielding and hybrid rice to varied levels of nitrogen nutrition. *Environ. Ecol.* **21**(2): 296-300.

Manickam, T. S. and Ramaswami, P. P. (1985). Influence of N level and source on rice yield. *Intl. Rice Newsl.* **10**(5): 28.

Masum, S. M., Ali, M. H., and Ullah, M. J. (2008). Growth and yield of two T. aman rice varieties as affected by seedling number hill^{-1} and urea supergranules. *J. Agric. Educ. Technol.* **11**(1 & 2): 51-58.

Masum, S. M., Ali, M. H., and Ullah, M. J. (2010). Performance of seedling rate and urea supergranules on the yield of T. *aman* rice varieties. *J. Sher-e- Bangla Agric. Univ.* **4**(1):1-5.

Miah, M. A. M. and Ahmed, Z. U. (2002). Comparative efficiency of the chlorophyll meter technique, urea supergranules and prilled urea for hybrid rice in Bangladesh. **In**: Hybrid Rice in Bangladesh: Progress and Future Strategies. Bangladesh Rice Res. Inst. Pub. No.138. pp. 43-50.

Miah, M. H., Karim, M. A., Rahman, M. S. and Islam, M. S. (1990). Performance of Nizersail mutants under different row spacing. *Bangladesh J. Train. Dev.* **3**(2): 31-34.

Miah, M. N. H., Talukder, S., Sarkar, M. A. R. and Ansari, T. H. (2004). Effect of number of seedling hill^{-1} and urea supergranules on growth and yield of the rice cv. BINA Dhan 4. *J. Biol. Sci.* **4** (2): 122-129.

Mikkelsen, D. S., Jayaweera, G. R. and Rolston, D. E. (1995). Nitrogen fertilization practices of low land rice culture. **In**: Nitrogen fertilization in the environment. pp. 171-223.

Mirzeo, W. A. and Reddy, S. N. (1989). Performance of modified urea materials at graded levels of nitrogen under experimental and farmer's management conditions in low land rice (*Oryza sativa*). *Indian J. Agril. Sci.* **59**: 154-160.

Mishra, B. K., Dash, A. K., Jena, D. and Swain, S. K. (1999). Evaluation of placement methods for urea super granules in wet land rice (*Oryza sativa*) soil. *Indian J. Agron.* **44**(4): 710-716.

Mishra, B. K., Mishra, S., Dash, A. k. and Jena, D. (2000). Effect of time for urea supergranules (USG) placement on low land rice. *Annals of Agril. Res.* **20**(4): 4, 443-447.

Mishra, P. C., Sarker, A. K. and Mishra, B. (1994). Relative efficiency of different nitrogen sources in transplant rice of chotanagpur region. *J. Indian Soc. Soil Sci.* **42**(2): 333-335.

Mohanty, S. K., Chakravorti, S. P. and Bhadrachalam, A. (1989). Nitrogen balance studies in rice using 15 N-labeled urea and urea supergranules. *J. Agric. Sci.* **113**(1): 119-121.

Molla, M. A. H. (2001). Influence of seedling age and number of seedlings on yield attributes and yield of hybrid rice in the wet season. *Int. Rice. Res. Notes.* **26**(2): 73-74.

Murthy, K. N. K., Shankaranarayana, V., Murali, K., Jayakumar, B. V. (2004). Effect of different dates of planting on spikelet sterility in rice genotypes (*Oryza sativa* L.). *Res. Crops.* **5**(2/3): 143-147.

Nayak, P. L., Mandal, S. S., Das, M. and Patra H. P. (1986). Effect of granulated, coated and prilled urea on the growth and yield of rainfed low land rice. *Environ. Ecol.* **4**(4): 602-604.

Nematzadeh, G. A., Arefi, H. A., Amani, R and Mani (1997). Release of a new variety of rice, namely "Nemat" with superiority in yield and quality. *Iranian J. Agric. Sci.* **28**(4): 79-86.

Om, H., Dhiman, S. D., Nandal, D. P. and Verma, S. L. (1998). Effect of method of nursery raising and nitrogen on growth and yield of hybrid rice (*Oryza sativa*). *Indian J. Agron.* **43**(1): 68-70.

Patel J. R. (2000). Effect of water regime, variety and blue green algae on rice (*Oryza sativa*). *Indian J. Agron.* **45**(1): 103-106.

Patel, S. R. and Chandrawanshi, B. R. (1986). Sources and methods of N application for driiled, rainfed low land rice. *Intl. Rice Res. Newsl.* **11**(1): 26.

Patel, S. R. and Mishra, V. N. (1994). Effect of different forms of urea and levels of nitrogen on the yield and nitrogen uptake of rice. *Advn. Pl. Sci.* **7**(2): 297-401.

Prasad, R. and Datta, S. K. D. (1979). Increasing fertilzier nitrogen efficiency in wetland rice. **In**: Nitrogen and Rice. Intl. Rice Res. Inst., Los Banos, Philippines. pp: 465-479.

Quayum, A. and Prasad, K. (1994). Performance of modified urea materials in rainfed low land rice (*Oryza sativa* L.). *J. Res. Bisra Agric. Univ.* **6**(2): 131-134.

Rafey, A., Khan, P. A. and Srivastava, V. C. (1989). Effect of Nitrogen on growth, yield and nutrient uptake of upland rice. *Indian J. Agron.* **34** (2): 133-135.

Rahman, M. A. (2003). Effect of levels of urea super granules and depth of placement on the growth and yield of transplanted *aman* rice. MS(Ag.) Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh. p. 100.

Rajendra P., Shaarma, S. N., Surendra, S. and Zaman, F. U. (1998). Productivity of hybrid rice pusa HR3 under late planting conditions. *Ann. Agril. Res.* **19**(1): 92-93.

Raju, R. A., Hossain, M. M. and Nageeswariq, R. M. (1987). Relative efficiency of modified urea materials for low land rice. *Indian J. Agron.* **32**(4): 460-462.

Rakesh, K., Rajesh, K. and Sanjeev, K. (2005). Effect of nitrogen and potassium levels on growth and yield of hybrid rice. *J. Applied Biol.* **15**(1): 31-34.

Rama, S., Reddy, G. and Reddy, K. (1989). Effect of levels and sources of nitrogen on rice. *Indian J. Agron.* **34**(3): 364-366.

Rashid, M. A., Billah, K. A., Mazid, M. A. and Jameel, F. (1996). Nitrogen use Efficiency of Urea Supergranules and Prilled Urea in Irrigated Rice Cultivation. *Bangladesh Rice J.* **7**(1&2): 41-44.

Reddy, G. R. S., Reddy, G. B., Rmaiah, N. V. and Reddy, G. V. (1986). Effect of different levels of nitrogen and forms of urea on growth and yield of wetland rice. *Indian J. Agron.* **31**(2): 195-197.

Rekhi, R. S., Bajwa, M. S. and Sattar, T. L. (1989). Efficiency of PU and USG in rapidly percolating soil. *Intl. Rice Res. Newsl.* **14**(2): 28-29.

Roy, B. C. (1999). Nitrogen fertilizer management and its effects on growth and yield of rice varieties in Bangladesh. Ph.D Dissertation. Verlag Grauer, Stuttgart, Germany. p. 50.

Roy, B. C., Mazid, M. A. and Siddique, S. B. (1991). Efficiency of different forms and application methods of N fertilizer on rainfed low land rice. *Bangladesh Rice J.* **2**(1&2): 75-78.

Sahu, G. C., Behera, B. and Nandu, S. S. K. (1991). Methods of application of urea supergranules in low land rice soil. *Orissa J. Agril. Res.* **4**:1-2, 11-16.

Sahu, S. K. and Mitra, G. N. (1989). Comparative efficiency of large granule urea (LGU) and prilled urea (PU) on wetland rice. *Fert. News.* **34**(2): 31-33.

Sarder, N. A., Shamsuddin, A. M. and Khan, N. H. (1988). Yield and yield components of wetland rice under various sources and levels of nitrogen. *Philippines J. Crop Sci.* **13**(3): 155-158.

Satrusajong, A., Snitwongse, P., Buresh, R. J. and Frisen, D. K. (1991). Nitrogen^{-15} and sulphur^{-35} balances for fertilizers applied to transplanted rainfed low land rice. *Fertilizer Res.* **28**(1): 55-65.

Sawant, A. C., Throat, S. T., Khadse, R. R. and Bhosalef, R. J. (1986). Response of early rice varieties to nitrogen levels and spacing in coastal Maharashtra. *J. Maharashtrta Agril. Univ.* **11**(2): 182-184.

Sen, A. and Pandey, B. K. (1990). Effect on rice of placement depth of urea supergranules. *Intl. Rice Res. Newsl.* **15**(4): 18, 51.

Setty, R. A., Devaraju, K. M. and Linagaraju, S. (1987). Response of paddy to different sources and levels of nitrogen under transplanted condition. *Oryza*. **24**(4): 381-382.

Shahjahan, M. (2007). Modern rice in Asia: Role in food security and poverty alleviation. Financial Express.htm. *vol. no. regd.no. Da.* 1589.

Shamsuddin, A. M., Islam, M. A. and Hossain, A. (1988). Comparative study on the yield and agronomic characters of nine cultivars of *aus* rice. *Bangladesh J. Agril. Sci.* **15**(1): 121-124.

Singh, B. K. and Singh, R. P. (1986). Effect of modified urea materials on rainfed low land transplanted rice and their residual effect on successding wheat crop. *Indian J. Agron.* **31**: 198-200.

Singh, G. O. P., Yadav, R. A., Singh, R. S. and Singh, B. B. (1993). Effect of sources and levels of nitrogen on grain yield, yield attributes, N uptake, recovery and response by rice in deep water conditions (100 cm). *Crop Res. Hisar.* **6**(2): 213-216.

Singh, G., Singh, O. P. and Yadav, R. A. (1991). Nitrogen management in transplant rice under rainfed lowland condition. *Indian J. Agron.* **36**: 234-237.

Singh, S. and Gangwer, B. (1989). Comparative studies on production potentials in traditional tall and improved rice cultivars. *J. Andaman Sci. Assoc.* **5**(1): 81-82.

Singh, S. and Shivay, Y. S. (2003). Coating of prilled urea with eco-friendly neem (Azadirachta indica A. Juss.) formulations for efficient nitrogen use in hybrid rice. *Acta Agronomica Hungarica.* **51**(1): 53-59.

Singh, S. P. and Singh, M. P. (1997). Response of dwarf rice cv. Jaya to different rates, methods and forms of urea materials. *Environment and Ecology.* **15**(3): 612-613.

Son, Y., Park, S. T., Kim, S. Y., Lee, H. W. and Kim, S. C. (1998). Effects of plant density on the yield and yield components of low-tillering large panicle type rice. *RDA J.Crop Sci. I.* **40**: 2.

Sumit, C., Pyare, L., Singh, A. P. and Tripathi, M. K. (2004). Agronomic and morpho-physiological analysis of growth and productivity in hybrid rice (*Oryza sativa* L.). *Ann. Biol.* **20** (2): 233-238.

Suprithatno, B. and Sutaryo, B. (1992). Yield performance of some new rice hybrids varieties in Indonesia. *Int. Rice Res. Newsl.* **17**(3): 12.

Surendra, S., Prasad, R. and Sharma, S. N. (1995). Effects of blue green algae, nitrogen levels and modified urea materials on yield attributes and yield of low land rice (*Oryza sativa*) hybrid as influenced by nitrogen sources and its split application. *Indian J Agron.* **44**(1): 80-88.

Swain, P., Annie, P. and Rao, K. S. (2006). Evaluation of rice (*Oryza sativa*) hybrids in terms of growth and physiological parameters and their relationship with yield under transplanted condition. *Indian J. Agric. Sci.* **76**(8): 496-499.

Swain, S., Goel, A. K. and Das, F. C. (1995). Evaluation of urea supergranule application methods. AMA (Agricultural Mechanization in Asia, Africa and Latin America). **26**(3): 24-28.

Thakur, R. B. (1991a). Relative efficiency of prilled urea and modified urea fertilizer on rainfed low land rice under late transplanting. *Indian J. Agron.* **36**(1): 87-90.

Thakur, R. B. (1991b). Effect of levels and forms of urea on low land rice under late transplanting. *Indian J. Agron.* **36**: 281-282.

Tomar, S. S. (1987). Effect of modified urea materials and N levels on transplanted rice. *Intl. Rice Res. Newsl.* **12**(4): 8-9.

Vijaya, D. and Subbaiah, S. V. (1997). Effect of methods of application of granular forms of fertilizers on growth, nutrient uptake and yield of paddy. *Ann. Agril. Res.* **18**(3): 361-364.

Wang, J. L., Xu, Z. J. and Yi, X. Z. (2006). Effects of seedling quantity and row spacing on the yields and yield components of hybrid and conventional rice in northern China. *Chinese J. Rice Sci.* **20**(6): 631-637.

Xia, W. X., Wang, G. H. and Zhang, Q. C. (2007). Potential production simulation and optimal nutrient management of two hybrid rice varieties in Jinhua, Zhejiang Province. *J. Zhejiang Univ. Sci.* **8**(7): 486–492.

Yoshida, S. (1981). Fundamentals of Rice Crop Science. *Intl. Rice Res.* Manila, Philippines. pp. 269-270.

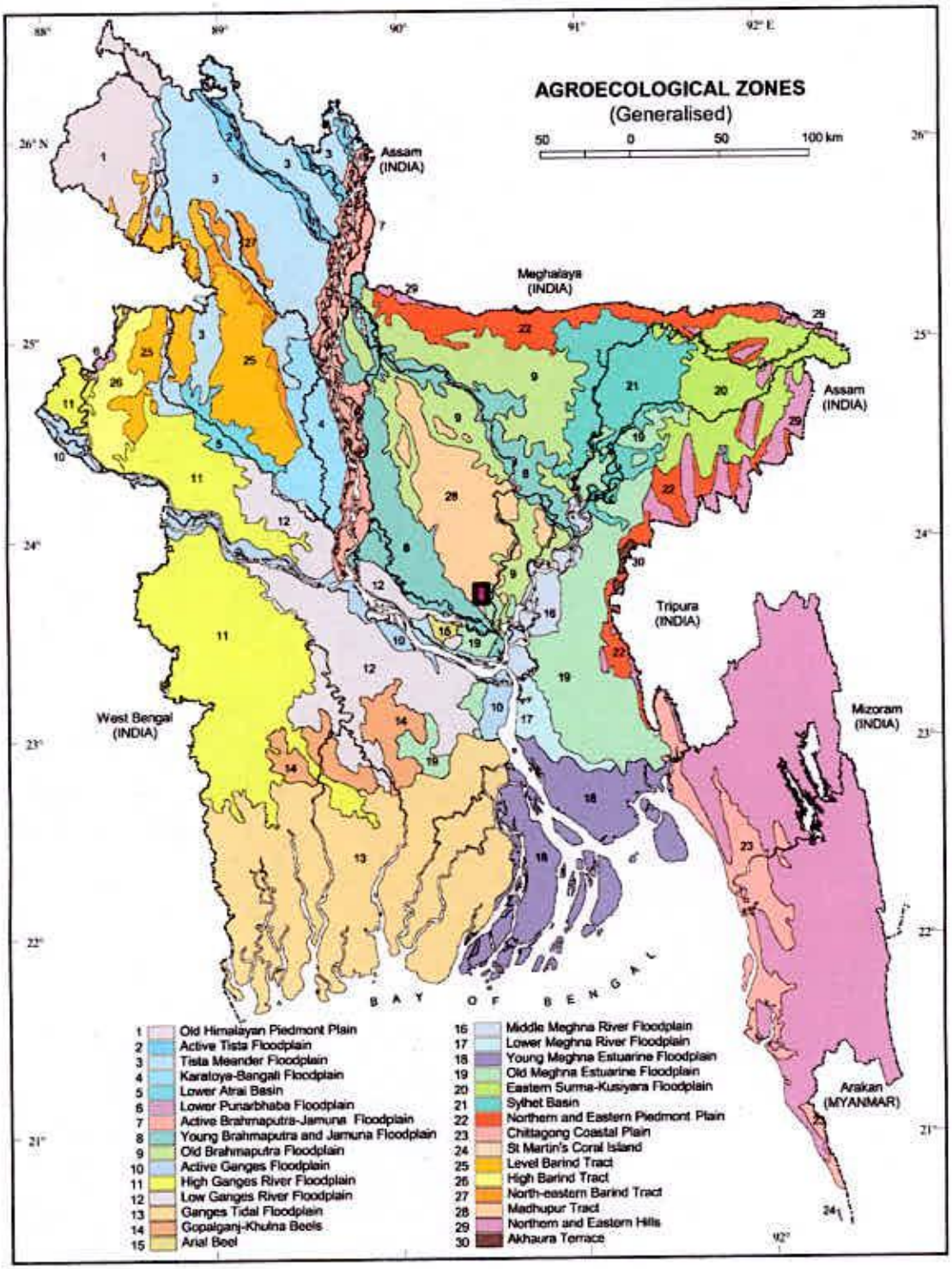
Zaman, S. K., Razzaque, M. A., Karim, S. M. R. and Ahmed, A. U. (1993). Evaluation of prilled urea and urea supergranules as nitrogen sources for upland *aus* rice. *Bangladesh Rice J.* **4**(1&2): 42-46.

Zia, M. S., Rashid, M. T. and Rahmutullah, (1988). Relative efficiency of conventional and slow release nitrogen fertilizer for rice growth. Indus. Res. National Agric. Res. Centre. P.O. NIH, Islamabad, Pakistan. *Pakistan J. Sci.* **31**: 9, 646-648.

Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II: Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological and chemical characteristics of the experimental field

Lab No.	Sample No	pH effect	Organic matter (%)	Total Nitrogen (%)	Potassium mM 100 g^{-1} soil	Phosphorus	Ghondok	Boron	Tama	Iron	Dosta
						$\mu g\ g^{-1}$ soil					
14058	T_0	5.3	1.21	0.061	0.11	19.3	3.38	0.11	2.4	266	2.3
		MA	Low	OL	Low	P	OL	OL	OH	OH	OH
14059	T_1	4.9	0.94	0.047	0.19	29.0	24.46	2.20	2.4	294	17.2
		LA	OL	OL	Medium	OH	P	OH	OH	OH	OH
14060	T_2	5.6	1.28	0.064	0.15	23.6	7.46	0.17	2.4	318	5.3
		LA	Low	OL	Low	High	OL	Low	OH	OH	OH
14061	T_3	6.0	0.94	0.047	0.11	19.4	3.95	0.04	2.6	336	4.2
		LA	OL	OL	Low	P	OL	OL	OH	OH	OH
14062	T_4	5.8	0.54	0.027	0.12	20.3	7.33	0.15	2.6	326	4.6
		MA	OL	OL	Low	P	OL	OL	OH	OH	OH
014063	T_5	5.4	1.55	0.078	0.13	21.1	5.50	0.12	2.61	290	4.0
		MA	Low	OL	Low	High	OL	OL	OH	OH	OH
14064	T_6	5.0	1.08	0.054	0.24	40.6	17.56	2.02	2.6	286	8.4
		MA	Low	OL	Medium	OH	Medium	OH	OH	OH	OH
14065	T_7	5.4	0.61	0.031	0.14	24.5	6.81	0.52	2.6	280	14.9
		MA	OL	OL	Low	High	OL	P	OH	OH	OH
14066	T_8	5.4	1.48	0.074	0.13	23.5	13.39	1.73	2.42	292	6.5
		MA	Low	OL	Low	High	Low	OH	OH	OH	OH
14067	T_9	5.3	1.21	0.061	0.15	22.9	12.22	5.90	2.6	282	7.2
		MA	Low	OL	Low	High	Low	OH	OH	OH	OH
14068	Soil	5.3	0.87	0.044	0.19	27.7	24.06	0.22	2.0	1.82	4.6
		MA	OL	OL	Medium	OH	P	Low	OH	OH	OH

MA= More acidity, LA= Less acidity, OL= Over low, L= Low, P= Perfect, OH= Over high

B. Physical properties of the initial soil

Soil sample no.	Soil ** sample	Sand	Silt	Clay
T_0	Silt loam	25.60	53.91	20.49
T_1	Silt loam	26.60	54.00	19.40
T_2	Silt loam	25.67	53.86	20.47
T_3	Silt loam	26.37	54.22	19.41
T_4	Silt loam	26.40	55.12	18.48
T_5	Silt loam	25.96	53.49	20.55
T_6	Silt loam	26.00	54.00	20.00
T_7	Silt loam	26.40	54.17	19.43
T_8	Silt loam	26.38	55.00	18.62
T_9	Silt loam	25.49	54.11	20.40
Soil	Silt loam	25.65	53.84	20.51

Appendix III: Monthly record of air temperature, rainfall and relative humidity of the experimental site during the period from October 2010 to March 2011

Month	Air temperature		Relative humidity (%)	Rainfall (mm) Total
	Maximum	Minimum		
October, 2010	26.11	18.05	77	19
November, 2010	25.82	16.04	78	00
December, 2010	22.40	13.50	74	00
January, 2011	24.50	12.40	68	00
February, 2011	27.10	16.70	67	30
March, 2011	31.40	19.60	54	11

* Monthly Average

Source: Bangladesh Meteorological Dept (Climate and Weather Division), Agargoan, Dhaka- 1207

Appendix IV: Analysis of variance (mean square) for plant height

Source of variation	Degrees of freedom	Mean square on plant height (cm) at				
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Replication	2	32.20	107.84	186.51	107.02	33.52
Factor A	3	402.62	276.76*	215.91	52.62	120.72
Factor B	3	11.34	55.91	57.48	53.53	468.11**
AB	9	37.55	150.70**	86.93	141.88	76.80
Error	30	36.74	32.23	74.99	118.72	91.81

Appendix V: Analysis of variance (mean square) for number of total tillers m^{-2}

Source of variation	Degrees of freedom	Mean square on number of total tillers $hill^{-1}$ at				
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Replication	2	13.02	15.10	6.94	11.81	7.75
Factor A	3	9.06	48.87**	154.24*	130.28*	37.52
Factor B	3	9.72*	28.39*	110.91**	84.17**	69.08**
AB	9	5.19*	7.75	10.73	6.33	5.35
Error	30	2.15	6.66	12.23	9.77	9.14

Appendix VI: Analysis of variance (mean square) for leaf area index (LAI)

Source of variation	Degrees of freedom	Mean square on leaf area index at					
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	harvest
Replication	2	7.75	0.18	1.84	0.46	0.012	0.77
Factor A	3	37.52	0.050	4.95*	10.79*	6.73**	1.67*
Factor B	3	69.08**	1.73**	3.13**	4.81**	3.19**	0.56**
AB	9	5.35	0.22	0.36	0.34	0.26	0.08
Error	30	9.14	0.14	0.33	0.437	0.282	0.08

*= Significant at 5% level of probability; **= Significant at 1% level of probability

Appendix VII: Analysis of variance (mean square) for yield and harvest index

Source of variation	Degrees of freedom	Mean square on			
		Grain yield t ha^{-1}	Straw yield t ha^{-1}	Biological Yield t ha^{-1}	Harvest Index
Replication	2	4.42	3.94	16.63	0.00
Factor A	3	17.75*	9.35*	46.73*	0.03*
Factor B	3	65.40**	73.27**	296.93**	0.01**
AB	9	1.33	2.02	5.96	0.03
Error	30	2.55	1.29	4.00	0.01